

**USE OF THE INTERSTATE HIGHWAY SYSTEM
RIGHT-OF-WAY FOR MAGNETIC LEVITATION
HIGH SPEED TRANSPORTATION SYSTEMS**

HEARING
BEFORE THE
SUBCOMMITTEE ON WATER RESOURCES,
TRANSPORTATION, AND INFRASTRUCTURE
OF THE
COMMITTEE ON
ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE
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USE OF THE INTERSTATE HIGHWAY SYSTEM RIGHT-OF-WAY FOR MAGNETIC LEVITATION HIGH SPEED TRANSPORTATION SYSTEMS

FRIDAY, FEBRUARY 26, 1988

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
SUBCOMMITTEE ON WATER RESOURCES, TRANSPORTATION,
AND INFRASTRUCTURE,
Washington, DC.

The subcommittee met, pursuant to notice, at 10:45 a.m., in Room 406, Dirksen Senate Office Building, Hon. Daniel P. Moynihan [chairman of the subcommittee] presiding.

Present: Senators Moynihan, Stafford, Reid, Graham, Warner, and Durenberger.

OPENING STATEMENT OF HON. DANIEL PATRICK MOYNIHAN, U.S. SENATOR FROM THE STATE OF NEW YORK

Senator MOYNIHAN. Good morning. The Chair would like to apologize to our witnesses and our guests. Contrary to rumor, I have not been arrested, I was waiting to vote.

This is a regular hearing of the Subcommittee on Water Resources, Transportation, and Infrastructure on the subject of the use of the interstate highway system right-of-way for the use of a magnetic levitation rail—high speed transportation system. I have to correct myself. It is not a rail system, and that is what is unique about it.

We are dealing here with an issue which I would hope the country and the Congress will become increasingly interested in. We have at our hands a new mode of transportation, and as I think our distinguished scientists this morning will testify, it is the first such new mode of transportation since the beginning of manned flight which we date to I suppose 1903 in Kitty Hawk, North Carolina, which is essentially a technology in the late 19th century finally brought to successful use.

The prospect we have here is for a system of transportation which runs at speeds that are quite beyond anything available now. We have heard a great deal about the very special trains that the Japanese and the French run. The Japanese run a train I guess from Tokyo to Osaka that reaches about 160-mile-an-hour average speeds. The French do the same, running a train from Paris to Marseilles that goes very quickly. But these are simply highly perfected and finely tuned railroad trains, and they are nothing really that much out of the ordinary. The Royal Scotsman I think went

from London to Edinburgh in the 1920's at speeds about like that. They take a great deal of maintenance. The Japanese have to realign their rails every night.

As with any such technology, you can tune it up to its very highest level of performance at increasing costs and with decreasing returns.

What we are talking about here is a new technology, a mode of transportation that is not rail based, neither does it work from gravitational principles, it works from magnetic levitation. The principles and the applied technology were developed in this country, and we shall meet some of the persons this morning who did that development. Yet already we find other countries moving ahead of us.

It is a rather important point. Our revered chairman emeritus is here, and I would like to make the point with him. Automobiles are no longer a preserve of American manufacture in the United States, much less in the world. We know that. Airplanes increasingly are less so.

When New York City, for example, began to do its subway system, we came to learn that there was no place in the United States that manufactures a rail-based transit car. In all those three modes of transportation, rail, road, and air, we are either out of the competition or are facing very strong competition.

Now the question is, this new mode comes along; if we develop it, we shall be at the head of the technological innovation in this respect. If others develop it, we will be behind and for the first time clearly behind in a period after which we have been in the forefront. It was one thing to be a little behind in railroad development. We were catching up with the British. It will be another thing to be behind the Japanese because they will be moving ahead of us, or the French, or for that matter the British. I believe there is a magnetic levitation people mover in Birmingham, as I understand; not a long one, but—I see Dr. Kolm agreeing.

So it is up to us. The technology is there, the science is done. The science was done in the 19th century I think for the most part. We have a unique thing, which is to say that we have the interstate highway system as a right-of-way. If you had to build a new rail corridor up the East Coast, you couldn't do it. Increasingly there is less room over the main airports. There is just so much air space that you can get into Kennedy, into LaGuardia, into Logan and into Washington National. It will be that way in Los Angeles and Atlanta.

We have here the prospects of a system of transportation which is highly efficient, moves people along at speeds of 250 to 320 miles an hour, 300 miles an hour, half an hour Washington to New York, one hour Washington to Boston and so forth. We have it in our hands. We know how to do it.

This meeting is called to discuss who might do it and in what circumstances, and particularly to explore the very great uses of the interstate system as a right-of-way.

[Senator Moynihan's written statement follows:]

OPENING STATEMENT OF HON. DANIEL PATRICK MOYNIHAN, U.S. SENATOR FROM THE
STATE OF NEW YORK

Good morning. I would like to welcome the invited witnesses and guests to this hearing of the Subcommittee on Water Resources, Transportation and Infrastructure. Our objective today is to consider the use of the interstate highway system's rights-of-way for the construction of magnetic levitation systems. Recently, I introduced legislation (S. 2072) which would direct the Secretary of Transportation to issue regulations which would permit such construction to proceed on the interstate rights-of-way.

Our hearing today is the second time that the Subcommittee has considered magnetic levitation systems. At our field hearing on January 21 we heard from two witnesses on magnetic levitation transportation. These witnesses explained the fundamentals of magnetic levitation technology and how it could be constructed on the interstate highway rights-of-way. Today, we will explore these issues in more detail.

What has the Subcommittee learned about magnetic levitation transportation? We have learned that it is the next revolution in transportation technology—a space age system. And we also learned that magnetic levitation transportation is not the technology of the future—it is the technology of today.

It is about time. We have not experienced a quantum leap in passenger transportation technology since 1903 when the Wright Brothers flew at Kitty Hawk. Our ground transportation technologies are even older. The railroad is an early 19th century development; the automobile a late 19th century adaption.

We have also learned that the interstate highway system rights-of-way are indispensable to the development of a viable national magnetic levitation transportation system. There is simply no likelihood of putting together the necessary land for a new ground transportation system. Indeed, resistance to development and other factors have all but eliminated the construction of new airports in the United States. We have not completed one in over a decade.

Our existing transportation systems are also subject to heavy burdens. Automotive traffic poses serious congestion and maintenance problems for the interstate system. In many places, air transport suffers from even worse congestion problems. And both automotive and air transportation create environmental difficulties.

Maglev systems can be the solution. At speeds of over 300 miles per hour a maglev system could bring people from New York to Boston or Washington in a fraction of an hour. The safety hazards and congestion associated with automobile and air travel could be relieved. Maglev is also energy efficient and quiet.

These benefits are astounding, and are why I have introduced S. 2072. I want to see impediments to maglev development on the interstate highways eliminated. That is also why on October 16, 1987, I introduced the first legislation (S. 1794) to provide a blue print for a federal effort to assist in the development and implementation of a U.S. magnetic levitation system.

After all, U.S. scientists largely developed maglev technology in the 1960's and 70's. We will here from some of these same individuals today. In addition, it is U.S. scientists who have played the leading role in the recent superconductivity breakthroughs which could be applied to maglev transportation systems. But we are on the verge of losing our potential advantage in maglev and may well permit the commercial benefit to go to others.

Which others? Predictably, the Japanese and Germans. Indeed, the Japanese and the Germans have launched large maglev development programs. Both countries are aggressively seeking commercial opportunities. The United States, meanwhile, stopped its development efforts in 1975.

As I said at the January 21 hearing, it is time that we get back in the maglev race. In many ways it is a challenge that is as important as the space race that captivated the nation in the 1960s. Then we had fallen behind the Soviets. Today we have fallen behind the Germans and Japanese. President Kennedy's exhortation to the nation in 1961 regarding the space race could well be used to describe the maglev race: "... While we cannot guarantee that we shall one day be first, we can guarantee that any failure to make this effort will make us last."

Fortunately, we are not yet that far behind. The United States is in a favorable position to "leapfrog" what the Japanese and Germans have achieved and to take the lead fairly quickly—if we seize the opportunity.

Today we will hear from a panel of scientists who will explain the technology of magnetic levitation and how it could be constructed on the interstate rights-of-way. In addition, we will hear from members of the business community who believe a government-business partnership to develop maglev can be achieved. And we will

also hear from a local official who will explain just how innovative government officials can be.

First, we have Dr. Henry Kolm. A genuine pioneer of magnetic levitation technology in the 1960s, Dr. Kolm is the designer of the only existing U.S. maglev technology. A company with which he is associated is active in an effort to establish a maglev system in the Florida corridor. We were fortunate to have Dr. Kolm at our hearing in January.

Next, we will have a joint presentation from Dr. James Powell and Dr. Gordon Danby of the Brookhaven National Laboratory. As Dr. Kolm, these distinguished scientists are the pioneers of maglev technology, having published the first work in 1966 on maglev transportation.

Third, we will hear from Larry Johnson, Director of the Center for Transportation Research at the Argonne National Laboratory. Mr. Johnson has been in charge of a study being prepared for the Department of Energy on potential applications of superconductivity improvements to maglev technology, and the economic viability of maglev.

Our second panel will have three witnesses. We are delighted to have Dr. Carl Rosner, President of Intermagnetics General and a member of the Board of Directors of the Council on Superconductivity for American Competitiveness. We also have Dr. Richard Gran, Director of Advanced Concepts for the Grumman Corporation. We look forward to the advice of these two gentlemen on how to establish a business-government partnership to achieve the goal of maglev construction.

Finally, lest anyone doubt that maglev transportation is a present and not a future technology, we will hear from Mr. Richard Welch of the City of Las Vegas on the progress made by Nevada and California on the introduction of a maglev system in the Las Vegas-Southern California corridor. As is often the case, state and local governments are quick to embrace new ideas to solve regional issues. Over a dozen states have given serious consideration to high speed ground transportation, including maglev. It is now time for the federal government to do likewise.

Senator MOYNIHAN. Mr. Chairman, would you wish to make some comments?

Senator STAFFORD. Thank you, Mr. Chairman. I have no formal opening statement, but I am intensely interested in the subject matter. Late yesterday afternoon I had an opportunity to go over the material that was supplied to us in connection with very high speed trains.

I have only two comments. One, after listening to you, Mr. Chairman, is that a Canadian organization, a corporation called Bombardiere in Vermont still is making subway cars for anybody in this country who cares to buy them.

Senator MOYNIHAN. Yes.

Senator STAFFORD. The other is that it seems to me that in connection with Amtrak and the Montrealer which over the past years has run between this city and Montreal through Vermont en route could only make their run now from Springfield, Massachusetts to upper Vermont if levitation were possible at this time because the tracks are unsuitable for passage, and anybody traveling on the Montrealer now has to catch a bus in Springfield, Mass. to complete the voyage.

So for many reasons, including the enticing possibility we could levitate trains from Springfield, Mass. to White River Junction, Vermont, I am attracted to the idea.

Senator MOYNIHAN. And well you might be. I should say that, among other places, there is soon likely to be no room in the skies over Las Vegas. It seems to me that half the large aircraft in our country are buzzing around there.

I wonder if Mr. Reid would like to comment.

**OPENING STATEMENT OF HON. HARRY REID, U.S. SENATOR
FROM THE STATE OF NEVADA**

Mr. REID. Mr. Chairman, I have participated in a number of hearings that deal with this type of transportation. I served on the Science and Technology Committee in the House, and we had a number of hearings in this regard.

I am forever amazed at your unique ability to look into the future. The reason I say that is that the problem we have had all along with this type of transportation is not a question of whether it can be done, because it can be done, it is a question of where you are going to put the vehicles to do it.

I think this hearing today focuses on a unique possibility that it can be done under existing rights-of-way that we already have. So I look forward to this, and I look forward to it because, as you mentioned, we currently have underway an agreement that the stamp of approval has been given both by the Nevada State Legislature and the California State Legislature to try to implement a system between Las Vegas and southern California where millions of people are transported on a yearly basis anyway. This certainly would be a unique opportunity to move large numbers of people.

As I say, I think your unique ability to look into the future as you and your staff have done in preparing for this hearing certainly points us in the direction I think we should be looking.

[Senator Reid's written statement follows:]

**OPENING STATEMENT OF HON. HARRY REID, U.S. SENATOR FROM THE STATE OF
NEVADA**

Mr. Chairman, I am happy to be here today to hear testimony on using the interstate right-of-way for magnetic levitation high speed transportation systems. I would like to compliment Chairman Moynihan for his leadership in this area. The Chairman has argued eloquently for legislation designed to promote the development of American technology and to create this country's next transportation revolution. I admire Chairman Moynihan's foresight in this area.

I have a special interest in the development of magnetic levitation technology. Efforts are currently underway to build a high speed super train for the Las Vegas to Southern California corridor. Mr. Richard Welch, a Management Analyst on this project, is here today. I look forward to his testimony on the progress they have made in developing this project, which is so important to the City of Las Vegas. I am also interested in hearing the City of Las Vegas' views on Senator Moynihan's legislation to authorize the use of rights-of-way along Federal-aid highways for the construction of these advanced transportation systems.

I see on the witness list for today's hearing that we have a number of prominent scientists in this area. I am sure their testimony will be enlightening and I look forward to their statements.

Thank you Mr. Chairman.

Senator MOYNIHAN. Thank you, Senator.

I think it is the case that Nevada and Florida are the two States that want to try this.

Now to our panel, and a very distinguished group of scientists indeed. If you will all come up, gentlemen. First, Dr. Henry Kolm, who has appeared before us in the past, who is Chairman of the Management Executive Committee of Electromagnetic Launch Research and formerly a professor at MIT.

We have Dr. James Powell from Brookhaven. We welcome you, Dr. Powell. We were unable to work out our schedules at the last hearing. We also have Dr. Gordon Danby from Brookhaven Laboratory. Brookhaven is on Long Island in New York State.

Finally, Mr. Larry Johnson of the Argonne National Laboratory from Illinois.

Gentleman, I think our practice is just to have our witnesses speak in series as they are listed on the witness list. So, Dr. Kolm, that would put you first, sir.

STATEMENT OF DR. HENRY H. KOLM, CHAIRMAN, MANAGEMENT EXECUTIVE COMMITTEE, ELECTROMAGNETIC LAUNCH RESEARCH, INC.

Dr. KOLM. Thank you, Senator Moynihan, and thank you for the opportunity to testify before this committee on what I think is a very important issue for this country.

As you have said, railroads require rights-of-way which traverse the countryside virtually without a bend or grade and are no longer possible. Railroads are nineteenth century technology.

A new railroad from Tampa to Orlando to Miami, for example, would require between 300 and 500 grade crossings, it would carry only one-tenth as many people as one single highway lane, to put things in quantitative perspective. It is simply no longer relevant technology. It is not likely that any new railroad will be built in this country or anywhere else.

Nor do we have either the air space or the ground space for new airports, as you have pointed out. Again, to be a little more quantitative, J.F. Kennedy, which is a small airport by modern standards, occupies 7.5 square miles of prime land. That same land is enough for a 95-foot wide right-of-way from Boston to Washington. That's only one airport. Newer airports like Dallas-Fort Worth's or Toronto occupy 25 square miles. There simply is no room for new airports.

The real solution to our traffic problem is not faster trains or more airports. It is simply to make better use of our existing interstate highway system. Now that highway system was built under the administration of Eisenhower under the slogan "Safe at Seventy", as some of you remember. It has since been degraded by the Nixon administration to "Safe at Fifty-Five".

The challenge is simply to make that same system safe at 224, and not only that, but to make it carry at least ten times as many passengers per hour as the highway system does now. It is our only chance to solve the problem.

This essentially is the next revolution in transportation, to follow the one that took place in 1830 when railroads were invented, 1900 when automobiles were invented essentially, 1940 when airplanes became practical, and now we are in 1987. I think the time is ripe for technology to solve the problem because the technology has existed since the late sixties and has been pursued until 1975 when all further work was terminated.

The winning concept is a maglev system which is not a train. It is a system based on the electromagnetic analog of aerodynamic flight which is an unfamiliar concept to most people.

I just wanted to point out that everyone would understand why a paper dart glides through the air generating lift at the expense of drag, but there are very few people, even electrical engineers who would understand why, for instance, a magnet on the end of this

rod which doesn't interact with aluminum at all, as we all know, will float above aluminum if the aluminum is moving.

In other words, there is no history, no high technology innovation required. The principle of floating something above a traveling aluminum plane is a well established physical principle that happens to be unfamiliar.

Senator REID. Are you sure that wasn't some kind of magic?

Dr. KOLM. No. I will invite anyone who wants to, to come up afterwards and hold it. I realize that it is one the end of a stick, and I could be faking the whole thing, but you are welcome to try this. Also, I have background information which you can help yourself to which dates from the seventies. If we run out, I will mail some to anybody who wants it.

It is a sound principle. It was worked on. It was discovered by three groups in this country, one of them at Brookhaven, the others at MIT and Stanford. It was pursued in this country between 1970 and 1975 with money from both industry and the government, and it was terminated in February 1975 by the Office of Management and Budget, on February 9th to be exact.

Senator MOYNIHAN. Could I interrupt, Dr. Kolm, to tell Senator Reid that we are going to address this subject. We were well on our way to being right on top of this, and OMB cut off the research in 1975, just cut it off.

Dr. KOLM. I will send a videotape, a nine-minute videotape showing the successful operation of this system taken in 1974 to anyone who is interested in seeing it. I will put a sign-up sheet here afterwards.

In other words, this technology is not pie-in-the-sky, it is not in the phase of feasibility studies or paper studies. It is real, it has been worked on. We spent \$1 million in four years demonstrating it on a one-twenty-fifth scale model, and I have offered to build a one-sixth scale model down the mall at a cost of \$10 million, right in front of the Smithsonian for all to see, pointing out that this technology exists.

When we stopped working on it in 1975 the Germans and the Japanese did not stop working on it. The Japanese have spent \$700 million on it that they will admit so far, and they have wound up with something that looks more and more like a railway train. So we have lost the national initiative. We've done nothing for these last 13 years. I think it is high time that we resume what really is a very low level of expenditure.

I think it is ironical that a country that can afford \$3.5 billion for the superconducting supercollider can't afford something like \$10 million a year to regain our lost leadership in transportation. It staggers the imagination that this should be possible.

Basically the concept involved is based on what I demonstrated here, repulsive levitation, not to be confused with various other systems which make adequate people movers which operate at a levitation gap of an eighth of an inch or so. This would float at a height of about 12 inches. The basic difference between this and a railroad is that a railroad carries 1,000 passengers once or twice an hour over an enormously expensive and cumbersome right-of-way, whereas magneplane would carry 100 passengers three or four times a minute, producing a steady flow of passengers, having ten

times the capacity of an interstate highway, operating at 224 miles an hour.

That happens to be a magic number because that is the number at which the air drag becomes so great that it doesn't pay to go faster simply from energy reasons. The next generation will build vacuum tunnels, but the practical limit of present day technology, what we can do today reasonably is 224 miles an hour.

The vehicles would be synchronous. That means they would travel like a surfboard, and they could travel at really tight headways because they are electronically coupled. We wouldn't couple vehicles together mechanically, we would couple them electronically.

They would use one-tenth the wayside power that a railroad uses, and they would travel essentially nonstop. In other words, you wouldn't spend time accelerating all the people who didn't want to stop in the first place like a railroad does. It is a different concept.

It is bad that this has gotten associated with railways because railways are an obsolete thing, as people know. We don't want another railway. This is not another railway. I think it is very important to disassociate this concept in people's minds from the concept of the railway.

I have no time to go further into the detailed technology. As I said, I will be happy to mail anyone this package of information, the videotape if they are interested, and I will be happy to build a magneplane system if somebody can come up with the support.

Senator MOYNIHAN. Dr. Kolm, just remember we, first of all, kept you all waiting. We have plenty of time, but I think in the spirit of colleagues, as you are, if we hear all the panel first, then we will stay with it and come back to each other.

Senator Graham has arrived. Would you want to make an opening statement, sir? We've been talking about you.

OPENING STATEMENT OF HON. BOB GRAHAM, U.S. SENATOR FROM THE STATE OF FLORIDA

Senator GRAHAM. Thank you, Mr. Chairman. I am here to defend myself.

Mr. Chairman, I am very pleased that you are holding this meeting today. I know that you have had a special interest in the fact that the United States at one time was the innovative leader in transportation in the world and now seems to increasingly look to other nationalities for that leadership.

This represents a technology in which the United States did much of the basic research, and now the challenge is how can we be the leader in applying that.

Representing a State which has had a strong interest in new forms of transportation and specifically high speed land transportation, I am especially interested in what will be developed at this hearing today and subsequently. The use of existing corridors that are currently constrained to a single purpose such as interstate for a broader and multiple use purpose and therefore eliminating one of the barriers that have existed to the application of new high speed land transportation is an issue of special interest.

Senator MOYNIHAN. We were just saying that the two States that have concerned themselves are Florida, when you were Governor, and Nevada.

We are going to have a very special moment now for this committee. Dr. Powell and Dr. Danby are the two theoretical physicists who developed this concept, in 1966 as I understand, we will hear from them.

I ask my colleagues to think a moment. The British got themselves into the situation where their physicists could think up anything, but their engineers never built them. Our engineers built them. We are going to hear from two physicists who discovered this principle. This is what they discovered, and here are the Japanese—if you want to know how to build one, there you are. That is a pattern which won't get you far in the modern world.

We welcome you, gentlemen. It is a great distinction for this committee to have two scientists of your stature before us.

STATEMENT OF DR. JAMES POWELL, BROOKHAVEN NATIONAL LABORATORY

DR. POWELL. Thank you, Senator Moynihan, and members of the committee.

I would like to briefly touch on the background and status of magnetic transport and then comment on the benefits to the United States and the conditions that are necessary for its implementation here.

As Senator Moynihan said, we published the first work in 1966 on high speed trains and continued to work in this field and pioneered a couple of inventions which are now used in the Japanese national railway system. We were granted the first original patent on superconducting magnetically levitated trains.

There is a funny story in that regard. We got the patent in the United States, and the patent attorney said, "Well, do you want to acquire the Japanese rights for another \$500?" We looked at each other and said, no, it will never be built in Japan.

So we passed it up.

Senator MOYNIHAN. Oh, the life of the theoretical physicist.

Dr. POWELL. Right, not too practical.

We freely provided details of our work to programs in the United States and abroad. The Japanese program has been the strongest and most successful program to date. They have mastered the first challenge of demonstrating the feasibility of 300-mile-per-hour levitated trains. Their test track has demonstrated safe, reliable, and efficient operation. Their system is now ready for practical application.

However, I believe it is a first generation system. It has a high cost track which requires considerable field construction and dedicated rights-of-way.

We believe the real challenge is to develop magnetic levitation designs that use low-cost, mass-produced track sections that can be installed along existing rights-of-ways like highways with minimum field construction. If we could master this challenge, we can have large scale implementation of magnetically levitated transport.

Senator MOYNIHAN. I want to hear you say once again, installed along existing rights-of-way.

Dr. POWELL. Yes.

Senator MOYNIHAN. With minimum field construction.

Dr. POWELL. Yes. We believe that's possible.

Senator MOYNIHAN. That may just be what we did, not anticipating this, but that's what we spent 30 years doing.

Dr. POWELL. Yes. Right.

I would just like to comment briefly on the benefits of this. The benefits of travel time are obvious. The benefits of greater efficiency and reduction of environmental effects are also very real, but maybe not so obvious.

Consider a hypothetical magnetic levitation system built between say A and B, 250 miles apart. With a top speed of 300 miles per hour, which has already been demonstrated, trip time would be approximately one hour allowing for pickup and dropoff. The two-way track between A and B could easily carry 100,000 passengers per day using nominal 100-passenger vehicles on three-minute headings and assuming an appropriate load factor. At peak periods several vehicles would be coupled together, with about a maximum of 100 vehicles in operation.

It is very interesting that the peak system operating power, that is, total power for the system that is moving all these people, is only about 150 megawatts to overcome air and magnetic drag if you use a high efficiency, low drag system. The energy consumption for the trip would be about 15 kilowatt hours per passenger, equivalent to the energy available from a single gallon of gasoline. This is very small compared to that for auto or air travel for the same 250 mile trip.

One would need an additional energy expenditure of about 5 kilowatt hours per trip to refrigerate superconducting magnets on the levitated vehicles. This assumes present superconductors are used. Higher temperature superconductors would further reduce this very small value.

Since most of this modest electrical energy consumption would come from power plants, oil fuel use per passenger trip would be essentially zero. If all U.S. transport were by magnetic levitation, about 2 billion barrels of oil would be saved per year, resulting in greater energy security and a more favorable balance of trade.

It is unrealistic to expect that magnetic levitation could completely replace all other forms of transport, but it could significantly reduce oil use.

In terms of implementation, we believe there are three fundamental conditions. First, you have to have a practical technology, acceptable economics, and an effective constituency.

Practical technology we believe is virtually here in terms of the demonstration, as I said, of speed, efficiency, reliability and safety.

Senator MOYNIHAN. Could you tell us, Dr. Powell, you said that 300 miles per hour had been demonstrated.

Dr. POWELL. In Japan. But the Japanese structure is relatively massive and requires a lot of field construction. Again repeating the point I made, we need a compact, low-cost, prefabricated track structure that can be installed existing rights-of-way. We do not need high temperature superconductors for a practical system.

They will help, but present superconductors are suitable for first generation systems.

Senator MOYNIHAN. They will help, but they are not essential. They are coming?

Dr. POWELL. They are coming down the road, and they will help. Basically I think they will help to demystify—the problem of getting new technology implemented is part economic and part mystification. Four degrees Kelvin mystifies a lot of people, they don't understand it. Room temperature or refrigerator temperatures they understand. So if you can have that kind of technology available, people will feel more comfortable with it, but it is not a necessary condition.

Senator MOYNIHAN. That's a nice point.

Dr. POWELL. Acceptable economics is essential, we believe. Not only must the maglev travel cost be competitive with airplanes and automobiles, but its capital investment in track and vehicles must be low enough and the payback period short enough that systems can be financed. In that connection we believe that systems which also carry freight will go a long way to help defraying the cost of the investment for track.

Let us return to the hypothetical system between cities A and B. We estimate that if one pushes the technology towards the prefabricated construction route, a two-way track cost should be on the order of \$2 million to \$3 million per mile, not including right-of-way modifications. This would be based on compact prefabricated track structures that could be installed at grade or on preset pylons.

Assuming such a cost, the 250-mile track would cost about three-quarters of a billion dollars. With an additional \$1 billion for station, vehicles and power, total investment would be on the order of \$2 billion.

Senator MOYNIHAN. Sir, I am interrupting just because we are accustomed to talking, in this committee, about one mile segments of the interstate highway system that cost \$7 billion. You are talking about a 250-mile transportation system which can be put in place, stations and all, for \$2 billion.

Dr. POWELL. I am probably being unrealistic.

Senator MOYNIHAN. Call it three. That will get you a half a mile of interstate highway system.

Dr. POWELL. I think that looking at the kind of structures we can envision building, they don't require a lot of material, they do not require a lot of field construction, and they can be mass produced in industry. I think that's the key.

But taking such a system as an example, if you had an average of 30,000 passengers per day for the first few years at an average fare of \$30, the payback period would be about 10 years. That would probably be acceptable. We believe that traffic would actually be higher and there would be freight revenues. So the system as a whole, if you can keep the track cost down, would be very attractive.

Thirdly, we believe an effective constituency for magnetic-levitation has to be built. Constituencies already exist for auto and air transport. The constituency for maglev could be based on ties to existing groups.

Environmental benefits such as reduced energy consumption, cleaner air, and reduced land use will be very important to environmental groups. The economic and time benefits will be important to employers, developers, and planning commissions.

Public awareness of magnetic levitation and its benefits will provide a very powerful impetus, including articles, TV, and other media reports. But also important will be visits to demonstration systems. The people in charge of the Japanese system made a very important point to us. They said that part of the reason that they were able to build a constituency in Japan is that they had this test track and they had literally millions of visitors to this test track. It was a major high point for a Japanese tourist to come and see this track. I think we need that kind of philosophy if we are going to implement maglev in this country.

Senator MOYNIHAN. Dr. Kolm?

Dr. KOLM. I would like to point out that we have such a track. We built it at a cost of \$32 million in Pueblo, Colorado in the early seventies, and we have turned it out to pasture.

Dr. POWELL. I would like to conclude by saying that we believe that magnetic levitation can substantially improve U.S. transport with respect to speed, traffic capability, travel cost, reduced delays, and reduced oil consumption and pollution. But to implement maglev in the United States, a strong government initiative is necessary. We believe the focus should be on mobilizing U.S. industry and finding the optimum systems and then demonstrating them on a scale that would convince people who want to implement an actual system to go ahead with it.

Thank you.

Senator MOYNIHAN. Could I ask you, Dr. Powell, where is the Japanese National Railway test facility?

Dr. POWELL. Miyazaki.

Dr. KOLM. Miyazaki.

Senator MOYNIHAN. How long is it?

Dr. POWELL. Seven kilometers.

Senator MOYNIHAN. I see. So you can get on for two and a half minutes or whatever.

Dr. POWELL. I think they reserve the trips for the VIP's, but people visit it just to look at it and see it operate.

Senator MOYNIHAN. I hope everybody will want to break in.

Dr. Danby.

STATEMENT OF DR. GORDON DANBY, BROOKHAVEN NATIONAL LABORATORY

Dr. DANBY. Thank you, Senator Moynihan, Senators.

Jim and I are very appreciative for this opportunity to speak to you on this subject. We strongly support the timeliness and importance of your initiative. We have been at this work since 1960. In fact, our original patent has expired. This is our on and off hobby project and really private. In fact, we obtained the word "hobby" from the IRS which was a description of a consistently nonprofit enterprise.

Originally Jim was going to represent both of us, but my director and chairman kindly said in the interest of this that the lab would

pay our travel expenses. I went to the division leader who has to actually cough up the dough for the department, and he grumbled. He said he would sign it as long as I told you gentlemen that high energy physics at Brookhaven is in desperate financial straits. So I've told you.

Senator MOYNIHAN. So noted.

Dr. DANBY. I will only emphasize a few points in support of our written statement.

The Japanese National Railway has successfully demonstrated magnetic levitation and propulsion of multiple car vehicles. They carry selected passengers, and have performed extensive experiments for years now, such as deliberate large track dislocations at very high speeds. They have done an excellent job—intelligent and thorough.

You have to bear in mind that Japan is a different topology than much of the United States. More than half of any train system is going to be hard rock tunneling. That puts a very different perspective on the system that you might use. It depends on the geography obviously.

I want to just extemporize on something that Jim said. The Japanese were very early enthusiasts. I stood at Tokyo Airport with my nonexistent Japanese with a gentleman with nonexistent English, and I pulled out a picture of the train when I was going to Miyazaki, at their expense by the way, and he grinned, and he said, "Ah, linear motor." They got into this originally because this system also solves the question of offline propulsion which is a serious impediment to trains if you don't want to burn junk on board. So it was originally called that, and then they very intelligently developed it.

In fact, my Japanese high energy physics colleagues tell me off the record that the decision to go beyond the test track to the beginning of a real system has been made. That's something you can probably officially confirm, but that's the gossip at the laboratory from these people.

Senator MOYNIHAN. Can I hear you again on that, Dr. Danby, that the decision to go from a test track to a transportation system has been made? You hear that?

Dr. DANBY. That is informal laboratory conversation with Japanese colleagues. Perhaps you can confirm it so it is official. I don't want to be a spokesman for the Japanese National Railway, but it is something you can look into if you would.

For projects with large scale implications, which certainly transport is, the go-ahead to funding is always very difficult. Many questions arise: does it basically work or is it a technical boondoggle? This has been put to rest for maglev by the Japanese railway, at least at the fundamental level. A U.S. program can start to build from this achievement and move on to second generation ideas and applications more appropriate to the varied U.S. situations.

How does it basically work? Superconductivity permits very strong but light magnets to be distributed along the vehicle. On the ground there is only a track of ordinary copper or aluminum conductors to levitate and propel forward the vehicle. Current is induced in the track for levitation only when the train magnets move directly overhead.

For all intents and purposes, it is a light strong permanent magnet, except we don't have such things without the mechanism of superconductivity.

The track is configured to hold the vehicle in a stable position or magnetic well, typically a half foot or so in the air, with automatic strong restoring forces if it goes off position.

The linear synchronous motor works like household motors, except that the magnet poles move in a line instead of going around in a circle over and over again. Because the superconducting magnets are so strong, only low current windings in the ground are required—this is very important practically—for strong propulsion forward. It is exactly like a wave acting on a surfboard. The speed is automatically determined by the frequency and the spacing of the magnets. If the vehicle falls slightly behind, it will get pushed harder. If it gets a little ahead, the push will weaken.

So both for propulsion and levitation, this is an automatically self-stabilizing system. It doesn't depend on something cranking fast to avoid a crash. So it is inherently stable, and this makes for great simplicity and safety.

Magnetic levitation involves potential energy. This is a very important point because there is no fundamental law of nature that says energy must be dissipated by levitation. In practice for our designs, the losses for levitation are extremely small. Even for propulsion, the energy consumed due to purely electromagnetic causes is very small. Most of the energy consumed is to push the air out of the way. This air drag is independent of the payload carried inside the vehicle. As a result, we have developed design concepts for both lightweight passenger vehicles and heavy freight vehicles.

We make this point because maglev is usually not considered in the context of freight or mixed-mode transport. We know how to move heavy freight at high speeds with very little energy consumption.

The United States is a very large country with diverse transportation needs. There is a great variety of terrain and population density. An evolving maglev system should ultimately be easily and economically adaptable to varied situations.

Maximum exploitation to the extent practical of existing rights-of-way is highly desirable. For example, a casual observer can see that much of our interstate highway system is straighter and more level than would be required if control of personal discomfort due to forces on the body were the sole criterion of design. It follows that in many locations much greater speeds than are practical for autos could be used before passengers would become uncomfortable from the roller coaster effects of going over hills and around corners.

Different speeds are possible. Starting and stopping already requires variable frequency propulsion currents. In principle, some locations could operate at different speeds from others to conform to the realities of available road beds or even length of trip.

We have perhaps raised issues which go beyond the scope of any initial utilization of maglev transport. The first system might be located in a very heavily populated corridor, or might be between two cities with low population density in between. The first application will probably be basically a people mover.

However, we would urge that the levitation technology chosen for development should be flexible enough in potential application that it is not eventually self-limiting. There are large portions of the country where only a major freight component can justify such systems.

A successful revolution in transport with its supporting infrastructure development must be based on significantly increased mobility. Large scale usage requires savings in time and in cost, including energy. This applies to passengers and to freight.

Magnetic levitation can provide high speeds with low energy consumption if highly utilized for passengers or freight. Vehicle costs are modest. Track maintenance should be minimal, in contrast to conventional trains, since reaction forces on the tracks are very low because they are spread along the length of the vehicle.

In closing, it is worth noting that the very large labor costs of properly maintaining conventional railroad track roadbeds have played a very significant part in the deteriorated state of our wheels-on-steel railways.

Senator MOYNIHAN. I have to say to you gentlemen that we have a vote in progress. It is our second vote, and it is probably the last vote of the day. The final bells have rung. So we will stand in recess. This is a very brief five minutes.

[Recess.]

Senator MOYNIHAN. If our guests will be so kind, we will resume our hearing. A number of Senators are on their way. We are getting dangerously close to the weekend.

Dr. Danby, I think you had finished your presentation. So we will go to Mr. Johnson and then have the panel talk collectively.

Mr. Johnson, we welcome you.

STATEMENT OF LARRY R. JOHNSON, ARGONNE NATIONAL LABORATORY

Mr. JOHNSON. Thank you very much, Mr. Chairman. I had prepared the written testimony and given it to the committee earlier. So I would just let that be included in the record.

Senator MOYNIHAN. It will be included in the record and you say what you have in mind.

Mr. JOHNSON. I have oral testimony written and prepared, but I won't read it. I think I would just like to discuss a couple of issues briefly and then let there be questions.

Our examination of this issue has been from two perspectives: one is to look at the potential benefits of higher temperature superconductors for maglev systems. That falls on the cost side of the equation, but you wouldn't really implement a technology no matter how inexpensive it was if it didn't produce benefits. So we tried to look and determine whether there was actually a market for maglev vehicles and where that market would best be.

On the issue of superconductivity, it has already been discussed briefly by Jim Powell and Gordon Danby that the benefits are positive but slight. I would reinforce that to some extent, that you would have cheaper magnets and reduced cryogenics, refrigeration costs, less energy consumption in that respect.

It is possible that you could have less sheet aluminum in the guideway because higher temperature superconductors have associated with them larger magnetic fields. As the sheet aluminum or copper would run the length of the guideway, perhaps several hundred miles, then this offers a potentially substantial reduction in cost. But there are a lot of issues that are involved in that effect on which tradeoff analyses would have to be conducted.

The most important issue, I think, is probably that the reliability of the system is enhanced by operating with at least liquid nitrogen coolant rather than liquid helium so that excursions of a few degrees do not send the magnets normal.

As a final comment on superconductivity, we have also looked at a number of large-scale applications. You will hear mentioned such things as transformers and transmission lines, and superconducting magnetic energy storage, as well as maglev vehicles for large scale applications. All have relatively low field strength requirements, but the differences in transport current density vary considerably. They are at least at the level of an order of magnitude around 10^4 amps per square centimeter, and it is lowest at that threshold design level for maglev than it is for any of the other applications that I have mentioned, which may be one or two orders of magnitude higher.

What that means is that from a materials development point of view the superconducting materials may be available sooner for maglev application than they would be for these other large-scale applications. So it is a positive benefit in terms of maglev.

We think that the work that has gone on in Japan and in Germany which have most aggressively pursued maglev development, that they have not pursued it from a concept of both lightweight vehicles and unlinked, offline loading arrangements. This is very important because the guideway accounts for 60 to 90 percent of the cost of a maglev system. So if you can have lightweight vehicles, you can have a lightweight infrastructure or lightweight guideway and thereby reduce a substantial portion of the cost.

It is also important to have, we think, unlinked and offline loading and unloading of vehicles in order to maximize the amount of vehicles you could have going along the longhaul portion of the system. The brochure you held up a few minutes earlier showed the Japanese system has about a dozen to 14 vehicles linked together. It looks like a train. The Japanese have reportedly been having difficulty getting their system to go around curves. I find it interesting that they've got 14 of these linked up and showing an enormous curve in there. But they are treating it essentially as a railroad technology using magnetic levitation.

You are talking about transporting 1,000 people on one of these trains. As Dr. Kolm mentioned, the real issue is to have more frequent departures of vehicles with a smaller number per vehicle.

The Germans are pursuing a technology in which the vehicle itself weighs about 100 tons and carries about 100 passengers. So it is a fairly heavy system, and the guideway costs are enormous on that system.

So we believe if you were to undertake a program in magnetic levitation, that one of the design principles that ought to be pursued very early on is lightness of the entire system.

These are issues that are on the cost side, and I think that high temperature superconductivity and lightness are issues that are very important to bring the total system cost down to a manageable level and have a highly reliable system.

The real issue though is that with superconductivity you may have a technology that is all dressed up and no place to go if no one wants to use it. Most of the studies that have examined magnetic levitation in this country have compared it to high-speed steel wheel systems. The French TGV train and the Japanese Shinkansen train are examples. They have looked at them as going from downtown to downtown, one city to another city. But very few of us travel from the downtown of one city to the downtown of another. That's just not the picture of the trips that we make. That only addresses a portion of intercity travel and not even the major portion of it.

As we examined this issue, it became clear to us that there was a national problem, and that problem was air traffic congestion. Enplanements on aircraft have doubled in the last 15 years, and they are expected to double again by the year 2000. That's an enormous load on our Nation's airlines and airports. In fact, we lack the capacity now at our major airports to handle this volume of traffic.

The only alternative to increasing capacity substantially is to build new airports, and it is extremely difficult to build new airports because no one wants one next to them. It's okay to put it somewhere else, but not next to me. The last new airport that was built in this country was Dallas-Ft. Worth in the 1960's.

FAA has done some analysis on passenger delays. We have a dozen airports now with over 3 million hours of passenger delay a year. That number of airports with excessive delays are expected to double by 1996.

So I think we need to look for options that provide us with increased capacity for our intercity network without building new airports which, as Dr. Kolm mentioned, are on the order of \$2 billion to \$3 billion apiece to build. I think maglev is an option to do that.

As I was thinking about this conceptually, I had originally envisioned a Chicago to Milwaukee system since we are from that area. The original studies had looked at downtown Milwaukee to downtown Chicago and a maglev system versus a high-speed steel wheel system. The maglev system does it much faster, but it occurred to me that I could go from downtown Chicago to O'Hare, from O'Hare to Mitchell Field in Milwaukee, and on into downtown Milwaukee on a maglev system faster than I could go just downtown to downtown on a steel wheel system, and I would pick up additional revenue at the airports.

It also occurred to me that if I was to build a maglev system intercity, my immediate competitors would be the airlines. So what would I do if I was the airline? I would drop the fare sufficiently enough to keep that new technology out of the corridor, and once they were bankrupt I would go back to the normal fare structure.

So it occurs to me that why shouldn't we offer this technology to airlines as a technology option to them rather than as a competitor to them. For the airlines there are a number of benefits. Airports are already congested. We have the system of rationing slots at air-

ports because there is more demand for the airports than we can now accommodate. If you are flying into Chicago and want to go to Milwaukee and you are coming from Atlanta or Nashville or San Antonio or Salt Lake City, you fly to Chicago first, and you have to get off the airplane, walk down a corridor and get on another airplane in order to finish your trip to Milwaukee.

If you have to get off the plane in the first place, you could just as easily get on a maglev system as you could get on another airplane if it was available there at the airport. It would not only serve the next airport but could continue on then to the downtown area if you were able to utilize existing rights-of-way.

What this means for airlines is that they can offer a system to extend their familiar hub and spoke system cheaper than buying additional aircraft for which there is not capacity at the airports. Maglev systems would use less energy, and fuel costs are still about 50 percent of the airlines' operating costs, and they would use less expensive labor costs than hiring two pilots per plane to fly that same trip.

So operating costs should be lower, and they should be able to divert short haul flights to maglev and thereby open up longer haul slots which are the more profitable trips.

If it is viewed as an aerospace technology, then the aircraft manufacturers can be seen as logical manufacturers of the vehicles. If you have capacity restrained airports now, and will continue to have them in the future, then aircraft sales are by definition constrained. If you divert part of the traffic to maglev systems, then you have opened up another market for aircraft manufacturers to be able to continue to supply the demand for the short haul aircraft. You have opened up slots for longer haul aircraft, and so the demand for longer haul aircraft should increase, and for aircraft manufacturers that is the more profitable portion of their market. So it should be a profitable situation for aircraft manufacturers.

Passengers should benefit from lower cost and from reduced delays in the system.

Japan is pursuing, as we have all heard so far, maglev systems. It is my understanding that they are committing to building a superconducting magnetic levitated system initially between Narita Airport and Tokyo.

Senator MOYNIHAN. Is that what Dr. Danby had gotten word of?

Mr. JOHNSON. I think it may have been.

Dr. DANBY. I don't want to become the spokesman for the Japanese. I don't think that's it because, as far as I know, the Tokyo Airport to Tokyo system uses the Japan Airlines' technique which is one of those iron attractive servotrans like the Germans have. I didn't even get into that because we think that approach is a red herring.

I don't know the answer. I thought from the airport to the city there was a system like that in Germany.

Mr. JOHNSON. That's the HSST system. It was surprising to me to hear that they would build the repulsive system, but it is in the New Technology Week November 30th issue. This is also part of my written record, so it will be available to the committee members.

They are talking about doing two years of research on their current prototype design and then spending three years in development of a system to go from Narita Airport to Tokyo, 30 miles. It is not a long system, but it will demonstrate the technology. It is also important from a congestion effect, because even though it is 30 miles, there is so much traffic it takes an hour and a half to get there by car. By the maglev system they are expecting it will take ten minutes.

Senator MOYNIHAN. Ten minutes?

Mr. JOHNSON. Ten minutes.

Senator MOYNIHAN. Dr. Kolm?

Dr. KOLM. A very similar proposal was made in the seventies and also died a political death. It was simply that both New York City and Boston had missed their chance to build a reliever airport, Hartford was underserved by transportation because the interstate highway was not finished, and the proposal was supported by the New England Governors' Council to build a high-speed line from New York to Hartford to Washington, which is the straightest line anyway, thereby providing Hartford with the opportunity to act as a reliever airport for both New York and Boston. It made sense economically and traffic-wise and everything else, but again, it died a political death at the time Volpe was deposed as Secretary of Transportation. This is one of the things he championed.

Mr. JOHNSON. In the same issue of New Technology Week, which has a discussion in there by Masanori Ozeki, the president of the Railway Technical Research Institute in Tokyo, and they are the ones that conduct the maglev research in Japan, he was asked very pointedly the question of why the U.S. dropped out of the maglev race. His statement, which is in bold letters on the front section of that newsletter, is that: "in undertaking civilian research and development, the U.S. has forgotten how to identify what is vitally important and to be prepared to share the risk in developing it."

That seems to be a very accurate but unfortunate truism in much of our research today.

I would say that maglev is a technology that is technically feasible. It benefits, to some extent, from the newer higher temperature superconductors. But what is more important, it meets a vitally important national need, and that is in reducing congestion in inter-city travel.

There is a growing consensus among the people that I have talked to in both industry and government that maglev systems will be in this country by the late 1990's and that magnetic levitation will be the next transportation revolution. The real question I think is whether it will be U.S. or foreign technology that we will see in our own country.

Someone has talked about how far behind we were in maglev technology after having essentially invented the system back in 1966.

Senator MOYNIHAN. That was Dr. Powell and Dr. Danby.

Mr. JOHNSON. That's right. Germany and Japan are the leaders in it now because they are doing work in there. Canada has had a more active program than we have in the last few years. The Soviet Union reportedly is engaged in some of this work, and Romania has active work in this area.

Senator MOYNIHAN. Thank God. That's the first good news we have had, the Soviet Union is involved.

Mr. JOHNSON. So I think that we are somewhere around fifth or sixth in the world.

That's my remarks.

Senator MOYNIHAN. Thank you very much, Mr. Johnson. That concluding statement, there is a growing consensus that we will have maglev systems in this country by the late 1990's and early in the next century magnetic levitation will have become the next transportation revolution. The question remains whether it will be a U.S. or foreign technology.

Senator Reid, you were first here, sir.

Senator REID. Mr. Chairman, my first comment is, we have in the last several years attempted to show how bad government is, that government is the enemy, that anything government is involved in, let's get out of it. I've always resented that. But this administration has done a real good job of selling that concept to the American people: government is basically bad.

Here is an example, one of numerous examples, of where government must be involved. If government doesn't get involved, it won't happen. We have to get involved in this, and I think that we have to get involved yesterday. This has nothing to do with my parochial interest of the train between Las Vegas and Southern California.

Senator MOYNIHAN. It's not very parochial. It's twice the length of the Japanese archipelago.

Senator REID. In fact, Mr. Chairman, I'm very proud of the fact that the city of Las Vegas is involved in this. But the fact that Las Vegas is involved in this shows what has happened to this country. We are a rapidly growing area. These vehicles should be carrying massive numbers of people in our population centers: New York, Washington, that's where it should be.

I repeat, if there was ever an example of where the government should be involved and an example where the government is good—the government isn't bad—it is here. I think the three of us should get our act together and do something about it. It's a real shame.

I have been impressed with this hearing. I had many other things scheduled starting at 11:00, and I, frankly, cancelled them because of this hearing. I think that it's too bad that the relatively small amount of money that is needed—what does, one aircraft carrier cost now, about \$15 billion?

Senator MOYNIHAN. About \$15 billion.

Senator REID. For one aircraft carrier. How many are we building, two or three? Maybe only two. I think the cost is \$38 billion, so it is a significant amount of money to build those. With a fraction of the money that it would take to build one aircraft carrier we could revolutionize what takes place in this country today. It would have effect on people's lives.

Citicorp has moved to Nevada. They have an operation going there, a large credit card operation and now they have a bank. I had dinner recently with the new Nevada president of Citicorp, a man by the name of Stein. He was basically raised in New York. He traveled two and a half hours each way to work and back.

Senator MOYNIHAN. In New York?

Senator REID. In New York.

Senator MOYNIHAN. Yes, that's not hard.

Senator REID. It's an example of what is wrong with—

Senator MOYNIHAN. That's a good example of why he is in Nevada.

Senator REID. It certainly is. Other than that speech I have two questions.

Could you, Dr. Powell, or, Dr. Danby, tell me how you invented this? I mean, why?

Dr. POWELL. Well, I started thinking about it when I was stuck in a traffic jam on the way to Boston.

Senator REID. That's really it?

Dr. POWELL. Yes. I was in a four-hour traffic jam, and I started thinking about it. At that time both of us were unmarried, so we were sharing a house, and we started speculating on how it could be done and spend a couple of years doing studies.

Senator REID. It's sure an example of how the government has let you down and has really let this whole country down.

One last question. This is to Dr. Kolm. In your written testimony that you did not read, and we appreciate that because your off the cuff remarks were certainly enlightening, and we can always read your testimony as I have done, you said that Las Vegas received bad advice from a Canadian firm. Tell me what you mean by that.

Dr. KOLM. Well, the Canadian firm in question called Institute for Ground Transport was started by a group which appropriated the American technology and didn't mention in their entire report the existence of U.S. technology when they compared everything. They traveled all over the world and gave assessments of inappropriate and untried technologies that will not go fast, as they said, but they left out any mention of U.S. technology despite the fact that it was all available in the open literature starting in 1966 until 1975. Not one mention was made.

Senator REID. Mr. Chairman, I appreciate hearing this. I have been involved in this maglev—

Dr. DANBY. As a former Canadian, I'll point out he was an Englishman.

Dr. KOLM. I stand corrected.

Dr. DANBY. He never gave us credit either, so it's not a rational issue.

Dr. KOLM. David Atherton is responsible for this because he plagiarized without credit, and I will say this for the record, technology that he learned about from this country at meetings starting in 1972.

Senator REID. Mr. Chairman, a final comment. The reason I've been so fascinated with what I've heard here is that, I have followed this probably as closely as anyone in Congress because of what is going on in Las Vegas, and I always had the impression that we didn't know anything. That's why the city was going to Japan, the city council and all the people were going to Japan and to Germany, going everywhere. They should have stayed here.

Dr. KOLM. Mr. Reid, it is interesting to note the fact that there was a hearing at a congressional committee in West Palm Beach in April. The administrator of the Federal Railway Administration had never heard of any American maglev work, not this 1966 work

or the 1972, despite the fact that it had been supported by the Department of Transportation and the National Science Foundation over that period of time. He didn't know of its existence.

Dr. DANBY. May I comment on this, because in my primary business in high energy physics, I am involved in building lots of things. Our problem in fact goes beyond government. You know, it is commonly said that a lot of our basic industries after showing other people how to do it basically didn't keep up. It's worse than that because shrewd guys came along and figured out if you just made fence rails—I'm exaggerating to make a point—you could show a better bottom line. So often I can't buy things that I could have bought 20 years ago.

The reason I am raising this is not just to ramble. I have a lot to do with the Japanese. I really admire not only Mr. Kyatani and how they systematically went about this, but in other activities their industry and their government somehow cooperates, although they seem to be truly competitive, and their industry, if they decide a field may be relevant to making super megachips or what have you, will voluntarily do R&D work.

Now I'm not saying—we are a different social system—that we can go that far. But the consensus somehow develops so that they do things very intelligently. I don't think it is going to be forever that we do things first and then they do them later. They will soon do them first and better using a lot of approaches that perhaps we had better 30 or 40 years ago. So the problem isn't just government.

Relevant to this I think it indeed will take strong government leadership, as you said, Senator Reid, but it's got to not be just sort of a boondoggle where anybody can throw any system he wants in. There has to be somehow a mechanism that provides competition but keep the competition basically and technically sound.

Senator REID. There has to be a partnership between industry and the government, but the government has to be a partner. It's not a partnership if it's one-sided.

Dr. DANBY. Exactly. Everybody has to sincerely believe in the product and get there. I think somehow the Japanese have retained that or got that in a way that we used to have and we have tended to lose. I'm making a speech now.

Senator MOYNIHAN. Dr. Danby, you are giving Dr. Kolm fits. He wants to comment on something.

Dr. KOLM. I think this committee would be remiss in not taking note of the fact that sitting in the first row behind us witnesses is Dr. Carl Rosner at the aisle who is one of the people responsible for making practical superconducting materials available back in the sixties. He headed the effort at General Electric at the time producing the first really significant materials. He was rewarded by being kicked out of General Electric, as I recall. I may be simplifying.

The fact he pointed out to me is that in American industry there exists no method for rewarding anybody who has plans that extend more than one year to the next annual report. That's the real problem. Nobody wants to be first because it has been shown that it is more profitable to be second. The Japanese have a means of collaborating in these initial risks. If the industry of this country

tried to get together to do something, they would be nailed to the wall for infringement of antitrust laws.

Senator MOYNIHAN. It is a well known function. It's called innovator cost, and economists do understand it. But somehow we have to get over it.

Dr. DANBY. We still have much entrepreneurial activity. That's where we are still our strongest. But some of our base industries need to get back to the roots is all I'm saying. Forgive me for talking so much.

Senator MOYNIHAN. We asked you here to talk a lot.

Dr. DANBY. The development of superconductors by American small companies is an example of entrepreneurial activity involving the same kind of guys who started our big industries 80 years ago.

Senator MOYNIHAN. Senator Graham?

Senator GRAHAM. Mr. Chairman, I have some specific questions I would like to ask, but the comments of the last five minutes have led me to suggest that maybe at some point this committee which has had the historic responsibility for America's public investment in our Nation's technological future might look at some of the questions that have been raised.

One of those is why is it that we have fallen into a time frame of the evaluation of consequences which is shorter and shorter and therefore discourages long-term investment. What happened to our national cultural tradition of deferred gratification?

The second is the linkage of private and public energy for the public good. I think one of the great enactments of the Congress was the Morrell Act which fundamentally revolutionized American agriculture by bringing the intellectual component of the land grant college, the demonstration system, the county agent program of extending that knowledge to the farm. What is the 1980's and 1990's equivalent of the Morrell Act for this new area of technology?

I think those would be a couple of interesting fundamentals.

Senator MOYNIHAN. You're on.

Senator GRAHAM. I am intrigued by Mr. Johnson's suggestion that maybe the airlines are the natural partner in moving this forward. We had just been talking about that very subject a few minutes ago during the break.

Senator REID. We only have a couple of airlines left.

Senator GRAHAM. We have talked a lot and we've seen the pictures of the Japanese National Railway magnetic levitation system. I have visited that one. I understand there is also one that is being developed by Japanese Airlines. So the idea that this is something that fits into aviation technology and managerial and entrepreneurial skills is also an idea the Japanese have grasped.

Has there been any interest to date that any of you are aware of by aviation manufacturers, airline management or other affinity industrial areas in this technology?

Mr. JOHNSON. Well, as I mentioned in my remarks, the technology has always been presented as a railroad technology. So there have not been many opportunities for airlines to comment on this.

I have broached the subject with some of the technical staff at both Boeing Aircraft Company and Douglas Aircraft Company. It is

at the very initial preliminary stages of discussion. But when it is presented as an opportunity to extend their markets rather than as a competitor, then there is a receptivity to the discussion, and some interest has been generated.

I'm sure the management of both companies don't know that this discussion has gone on, but at least I am encouraged to see the technical staffs interested in it.

I have had in my office for a couple of hours the former chief economist for United Airlines. It took the full two hours to go through a discussion of why it logically makes sense for it to be an airline technology rather than a railroad technology, and he was very intrigued by it. I think we will pursue discussions with the airlines as soon as we have some time which will probably be next week.

I might mention that Lufthansa operates a railroad, and it goes from the Frankfurt terminal, right underneath their terminal, up to Cologne and Dusseldorf. The only way you can ride that train is if you have an airline ticket. So if you are flying into that country (most European countries have only one airline—the national airline) if you fly into Frankfurt and you want to go to Cologne, you can get on a train as part of the extension of the trip. I see that as an airline that views themselves as a transportation company, not just an airline.

Senator GRAHAM. One of the textbook examples of an industry which conceived itself into bankruptcy was at the turn of the century when the railroads were asked, what business are you in, and they answered quickly, we are in the railroad business. Had they answered it, we are in the transportation business, they were in the logical position to dominate trucking, commercial aviation, all the other forms of transportation. So it would be ironic if at the end of the twentieth century the airlines were asked the same question and gave the same bankruptcy imperative answer that the railroads had done 100 years earlier.

In terms of getting some American entrepreneurial momentum behind this, what do you sense are the disincentives or what incentives would be required? My experience is that our State of Florida set up, and we may have used the wrong word, but we called it a High Speed Rail Commission, to look at what could be done to encourage some new technology. We are now in the midst of receiving proposals based on a very elaborate request for proposal that was submitted by our State commission. Every group that is submitting a proposal, and there are approximately four or five, is a non-American group. We have a French group, a German group, a Japanese group, a Canadian group. We don't have any U.S. groups. That's just one piece of evidence of how retarded we are as a Nation in terms of seeing this as an area of capitalist opportunity.

What has brought us to this state?

Dr. DANBY. Mr. Johnson and you, Senator, are making I think a very good point, but it does require a right-of-way. Therefore, I think companies are going to have to be convinced that they won't just develop it and then it will sit somewhere.

I think your point about similarities to airplanes is excellent because the aircraft construction is similar to that of levitation vehicles. So it would be a natural evolution for them. But I don't think

we here should go too far in that analogy either because it, again, does require a track. Quite rightly, as these gentlemen are saying, you can send individual vehicles, but on the other hand if the payload is such that you have to send several vehicles at the same time, you may find there will be less energy pushing the air out of the way if you hook them together, or entrain them.

This gets into an area of detail as I kiddingly say to my mechanical engineer friends when they ultimately get the real tough problems to solve, it's an engineering detail. Sometimes you will hook these vehicles together. Why not? Then you don't have to move the air in front and behind every vehicle separately. That's not a criticism. Their points are valid. The system is very flexible so you can do both. But it is a tracked vehicle. It is logical for the aircraft industry and perhaps the airlines to get involved if they choose.

Senator MOYNIHAN. Could I say to Senator Graham that I heard Dr. Danby say something important, but if you are going to get into the development of the actual transportation technology, you want to know do you have a right-of-way. The airlines didn't have to think about that, there is that sky, and the early railroads didn't have to think about that because there was the Great Plains.

Senator GRAHAM. What I would hope that we might come out of this hearing with or in subsequent hearings is a listing of what those constraints are, one of which is an assured right-of-way. Some others might relate to sharing the R&D cost, others might relate to financing the system once it's ready to go from research to implementation so that we could be dealing with the total agenda in hopes that we would create an environment in which there would be some entrepreneurial interest in moving forward with this.

Dr. POWELL. I would add that you have to establish that there is a market at least through some sort of demonstration phase. I think the natural candidates to develop this technology are the aerospace companies. They really have the ability, the high tech capacity, engineering staff and so forth, but before they move into this they are going to have to be sure that there is some market at least through some demonstration track system and preferably further down the road.

It's not just a question of money. I think that they will have to devote a substantial fraction of their capabilities and staffs in order to develop the necessary engineering know-how in this area. So you've got to, I think, assure them that there is a market out there. But I think they will compete effectively to develop the best systems once they know that there is a market there.

Senator MOYNIHAN. Dr. Kolm?

Dr. KOLM. I think both Jim Powell and Larry Johnson are right in their assessment that the aerospace companies and the airlines have a significant role. So do other industries like aluminum and the construction industry, for that matter.

The airlines will tell you that every aircraft company which invested in public transportation lost all the money they invested: Boeing, Grumman, Lockheed, that's the story you'll get from the aerospace companies.

However, I would like to add a very important principle to what has been said.

Senator MOYNIHAN. When you say public transportation, you mean subways or things like that?

Dr. KOLM. No. Boeing did some innovative attractive maglev work. The Rohr Corporation supported it with their own money as—

Senator MOYNIHAN. You mean ground transportation?

Dr. KOLM. High speed ground transportation.

But the other important point that needs to be made, and ex-governor Graham is very instrumental in doing this, is the fact that any new system will have to be supported by the value it creates. That's a principle that we knew in 1830 and seem to have forgotten except for the Florida initiative. The value created, when you put a dot on the map and say this will be a station, you are creating an enormous amount of capital. That capital has to pay for the development. Mechanisms to draw the line between the final value created and the initial capitalization is the political challenge.

In Scandinavia they have known that since they built the first condominium community of Tapiola which is a textbook case of city planning. In this country we haven't done anything like that. We haven't had any regional planning. Now every single city is surrounded by an enormous potential of real estate value if the transportation is developed to feed it. We act as if we didn't know this.

Florida is the only venture in which government creates an environment in which private enterprise can do something. That's why we have a National Gallery of Art because the Mellons made money, not selling railroad tickets, but only railroad rights-of-way and stations. That kind of capital—the Florida venture will produce this value.

The State will contribute essentially nothing and private industry would reap the rewards of the investment. Government would facilitate it by making the environment right, by providing the imminent domain, tax free bond issues and so forth and so on.

Senator GRAHAM. If I could just expand on that, I think that again goes to the question of asking what business you are in. Even beyond being in the transportation business even in the highest form of technology that might be available you are really in the asset creation business.

If you could do an analysis of our interstate system and ask how much did the system cost to build, and then second, how much value was created because of where the system was built, I would not be surprised if the two numbers were quite similar; that is, that we created about as much wealth, asset by where the system was located as it cost to build the system.

From a public financing standpoint the problem was that the public paid to build the system, private interest, who by wise investment or fortuitous chance, happened to be where the system was located and got the benefit of the increased value.

I was struck visiting the French system, and I was told this, and I can't independently validate its truthfulness, that the largest shopping center in France is not in Paris but is at the terminus of the Paris-Leon high speed rail in Leo.

Why is it the largest shopping center in France if that is an accurate statement? It is because thousands of people very hour come

through that system, and that is the most desirable place to have your office or shop located.

So the theory of the financing of the Florida system is that you let the people who are going to make the investment in the transportation system also get the benefit of the asset development which that system will create.

I thank you for your generous remarks. I think it is a concept that we might want to incorporate as we look at what the Federal role could be in this.

Senator MOYNIHAN. Gentlemen, Senators, if it is agreeable to you, I think we are going to have to go on to our next panel which will be discussing these various things.

I want to thank, and I know we all want to thank these extraordinary able scientists and public servants. I want Dr. Danby to go back and say we heard an issue of high energy physics and so certify.

I have to ask Dr. Powell or anybody else one question. We have been trying to retrieve it up here and the synapses won't work. It was Leo somebody, I think Szilard—was it Leo Szilard, who was waiting for a traffic light in London and thought up fission?

Dr. POWELL. Yes. I think it was 1934.

Senator MOYNIHAN. In 1934. Leo came and Szilard came, and you confirmed.

All right. There you are on your way to Boston, four hours, and you thought magnetic levitation. Not bad.

Thank you. Thank you very much, all of you. It has been a great honor to have you here, and we are not done with you obviously.

Now we have a final panel which consists of persons who are actually involved in this matter: Mr. Carl Rosner of Intermagnetics General, Dr. Richard Gran of the Advanced Concepts of the Grumman Corporation, and Mr. Richard Welch who is the Management Analyst for the City of Las Vegas.

We welcome you, gentlemen.

We want to admire Dr. Kolm who is indefatigable in schlepping that great experiment around.

May I first say that Senator Pressler asked that a statement of his be included in the record. I would like to have our able reporter do that.

[Senator Pressler's statement follows:]

OPENING STATEMENT OF HON. LARRY PRESSLER, U.S. SENATOR FROM THE STATE OF SOUTH DAKOTA

Mr. Chairman, thank you for holding this hearing today to discuss the feasibility of using the Interstate Highway System right-of-way for a magnetic levitation super speed transportation system. I am anxious to learn a great deal more about the technologies of the magnetic levitation system.

Indeed, this future system could be the most advanced mode of transportation we might see in our lifetime. Its reality may only be a short number of years away. I certainly am intrigued by the technological advances required for such a system.

However, I do have reservations over this future mode of transportation. Specifically, I don't want rural America to be left out. Our rural states face a continuous struggle to obtain adequate transportation. In my home state of South Dakota, for instance, we have a never ending battle to maintain adequate airline service. In addition, we are one of the very few states not served by Amtrak. Should magnetic levitation become a reality, it is essential that rural America be included in the application of this transportation system.

Mr. Chairman, I look forward to hearing from today's witnesses and commend you for holding this meeting.

Senator MOYNIHAN. Mr. Welch, since Senator Reid is able to stay past the noon hour, perhaps you would begin your testimony, sir.

STATEMENT OF RICHARD WELCH, MANAGEMENT ANALYST, CITY OF LAS VEGAS

Mr. WELCH. Thank you, Mr. Chairman, Senator Reid.

I am here today representing the proposed Las Vegas to Southern California super speed train project.

Senator REID. Mr. Welch, if I could interrupt, we have your statement, and we and the staff have read it. What I personally would like you to do, and I think the chairman would agree, is just summarize your statement and give us some of the problems you are having in Las Vegas. As I said, we have the statement, and it really doesn't benefit us for you to read it to us.

Mr. WELCH. Okay, very good.

Senator REID. Is that okay, Mr. Chairman?

Senator MOYNIHAN. I am more than agreeable, sir.

Mr. WELCH. As you are aware, the city has been involved in the investigation of magnetic levitation as well as——

Senator REID. I would ask, do you have any comments on some of the testimony that has been given already.

Mr. WELCH. Yes. I will try to add that.

We have been looking at magnetic levitation and other super speed ground transportation systems since 1980 in the City of Las Vegas. As is indicated in the statement, we have been responsible for the completion of some very detailed feasibility analyses about the possibilities of this system.

These studies focused on several specific issues that dealt with things such as ridership, environmental impacts, socioeconomic impacts, the financability of this system, and of course technology assessment.

I might point out in reference to your question about the work done by the Canadian Institute of Guided Ground Transport who did the technology assessment work, that they did look at all of the known technologies in the world, and in fact, although this occurred before I joined the city, they had sessions held at City Hall in the City Council's chambers where various inventors and other scientists around this country came and made proposals on their systems. However, they were charged with the specific responsibility of identifying those magnetic levitation or other systems that were realistically deployable by our target date of 1995 which meant that they had to be ready for a decision to be made by the late 1980's because of the long construction process that is involved with one of these systems.

So among many other criteria, they had a specific criteria for looking for those systems that had either full size or nearly full size prototypes already in existence and under testing. I guess you could say they created a short list of four technologies, and unfortunately none of those were American technologies, although we certainly would have hoped that that would have been otherwise, and came with a final conclusion of two super speed ground sys-

tems that they felt were deployable by this target date. Those were the German transrapid maglev system, and the second generation of the French TGD system.

If I can, I would like to talk a little bit about the specific topic of use of rights-of-way. In the analysis that we did a great deal of focus was made on this question of rights-of-way.

I might point out first that with the completion of, and the positive completion of our studies which were completed in mid-1987, we proceeded then with the next step toward implementation. As you mentioned, both the state legislatures in California and in Nevada passed legislation last year which created the bi-state commission. This commission has a responsibility for many things, but one of the specific responsibilities is that of assisting the technology representative to acquire the necessary right-of-way to build the system.

We believe, based on the study that was done, that the interstate right-of-way for implementing this super speed ground transportation system between our two metropolitan areas makes the system cost effective and increases the chances for the project of being successfully—

Senator MOYNIHAN. You said the interstate right-of-way?

Mr. WELCH. Yes. In reaching this conclusion, we looked at several different routes that exist now between the two metropolitan areas. We looked at the existing railroad rights-of-way, we looked at the easement underneath the high tension power line, and we looked at the prospect of obtaining an all new right-of-way for an all new system, and then finally we focused on the interstate, in this case Interstate 15, right-of-way.

There are many factors that go into making the decision about which is best. One question is route length. The length of a route determines to a substantial degree the system cost and the travel time. The guideway installation cost in our system represents by far the largest portion of the total system cost. It is 80 percent of the total cost involved with the system.

This then points us towards identifying the right-of-way that is the shortest which will then result in the shortest travel time as well.

Senator MOYNIHAN. Mr. Welch, I don't want to be tedious, but would you restate that, the 80 percent figure?

Mr. WELCH. In our cost estimates the guideway and the electrification of that guideway represent 80 percent of the total capital costs involved with the system.

Senator MOYNIHAN. Guideway being the right-of-way?

Mr. WELCH. Well, the construction of the track, right. That would leave then 20 percent for the vehicles.

The existing railroad right-of-way was eliminated from consideration because of the length of that right-of-way.

The question of land acquisition came up for an all new system. Land acquisition for new transportation systems traversing large areas is often time consuming and costly. Thus, route selections which are likely to experience delays in land acquisition should be avoided as much as possible. The consideration of acquiring all new rights-of-way for a rail line was eliminated on the premise that it would not be cost effective.

Finally, the question of maximum grade limitations. Although magnetic levitation systems have substantial hill climbing abilities, the power lines traversing mountainous terrains were not limited by grade restrictions, and therefore they exceeded often in cases 10 percent which is the maximum grade that a maglev system can negotiate. Therefore, we had to eliminate the power line easement as a consideration for the right-of-way.

By using these criteria, the Interstate Highway System emerged as the best possible route for the super speed system. The route length was reduced to a minimum, the grades did not exceed the capacity of the vehicle, and land acquisition costs were held to a minimum.

The interstate highway also provided the best access to the guideway for construction and also for maintenance work. As you can imagine, the high power transmission lines were very remote, and even the rail right-of-way was difficult to get to for construction purposes.

In addition, the interstate right-of-way provided the best access for emergency evacuation of a super speed vehicle should such a situation arise.

Based on all these facts, the obvious route for the super speed system between Southern California and Las Vegas is to use the Interstate 15 right-of-way.

For that reason we are strongly in support of Senate Bill 2072 because it will clearly define the process by which rights-of-way along Federal aid highways may be used for these magnetic levitation systems. We wholeheartedly support the bill.

Thank you.

Senator REID. Mr. Chairman, it is clear that the major problem with this is the rights-of-way. Once we can get a handle on that, it would appear to me that there would be great progress made.

Senator MOYNIHAN. I think that is just clear from Mr. Welch's point, the person who has sat down and worked this issue out as a dollar and cents economic proposition. It is immensely fortuitous that we have those rights-of-way. You know, the interstate system is there.

Dr. Gran, you are next, sir.

STATEMENT OF DR. RICHARD GRAN, DIRECTOR, ADVANCED CONCEPTS, GRUMMAN CORPORATION

Dr. GRAN. Mr. Chairman, I am from Grumman Corporation, one of the aerospace companies that was mentioned in the earlier testimony.

Senator MOYNIHAN. Right.

Dr. GRAN. As you heard I guess in the earlier testimony, most of the scientific issues associated with high speed magnetic levitation are in hand. I don't think that there are any scientific problems associated with doing it. The Japanese are clearly doing it, and so are the French.

However, I do believe that there are still technical and political problems that have to be solved. In my written testimony I went into some of the history of the early steam locomotive, and I pointed out that it was 1797 when Richard Trevithick in England in-

vented the first trains, but it wasn't until 1830, 1831 that the actual first train was in operation. The reason was that it took that long to develop a track that was practical and to figure out how to make a right-of-way that was cost effective.

Senator MOYNIHAN. Nice. Nice.

Dr. GRAN. So if history is any indication, we have to figure out a way of cementing industry and government together to break the circle of indecision. Industry won't commit funds to building a train until somebody has said unequivocally we are going to do it, and government is not going to do it until they know how much it is going to cost and whether it is cost effective.

The bottom line of my written testimony is: We need to systematically study the problem so that we know exactly what to build. We have to do the R&D that is necessary to define a good system, and that R&D must focus in on the track design and the vehicle design with the track design being paramount. As was indicated by Mr. Welch, 80 percent of the cost or perhaps even more could be in the overall track design. The cost of the superstructure, the electric feed system, the track itself are really the drivers of the system.

Senator MOYNIHAN. Mr. Welch, can I get you to help us here. That 80 percent, is that exclusive of the land?

Mr. WELCH. In our cost estimates that is the case because we made the bold assumption that we would prevail and find some way to be able to use those rights-of-way without substantial cost.

Senator MOYNIHAN. I see.

Mr. WELCH. If you add the cost of acquiring land, especially when you get into metropolitan developed areas, there is a significant potential increase.

Senator MOYNIHAN. So you might end up with your vehicles at 5 percent or 1 percent?

Dr. GRAN. Clearly. I am assuming that. So that's really the issue as we see it in industry. I think that a demonstration system with the goal of solving those technical problems, both the train and track, will break that circle and that the government should begin funding an orderly program that first gives the research and technology development that is required. I think the emphasis should be on those technologies that are critical to a successful system.

We have talked at length about magnetic levitation, but there is also aerodynamics and the interaction of the train moving along the track. A significant savings in air drag can be sustained if you figure out a good way of minimizing aerodynamic drag and the way in which the train interacts with the track.

Senator MOYNIHAN. Dr. Kolm testified at an earlier hearing that there were optimal speeds here that were brought about by the problem of air drag.

Dr. GRAN. That's correct.

Senator MOYNIHAN. He talked about 224 I think.

Dr. GRAN. But it could be higher.

Senator MOYNIHAN. But if you got working at it, you might get your F-14.

Dr. GRAN. I think you are in the same position that you were in with the cars of the sixties and early seventies; until aerodynamics got to be a significant issue when fuel consumption got high. You will find that the way cars were being built and designed that they

were not aerodynamically efficient, and it just wasn't studied well enough. I believe that is somewhat the situation right now as far as magnetic levitation is concerned.

Senator MOYNIHAN. That's what you are good at at Grumman. Dr. GRAN. Right.

Senator MOYNIHAN. You like to work on those things.

Dr. GRAN. That's one of the reasons I think an aerospace company is probably the correct place for this kind of technology.

So I guess that the approach I have outlined would encourage industry to take reasonable financial risks to develop the transportation system, and I think that comes out of history because that's exactly what happened in the 1800's. I think the legislation that you are proposing would break the circle, and I think we could do it.

Senator MOYNIHAN. You are a welcome witness, Dr. Gran. Let's see, they tried wooden rails for a while, didn't they?

Dr. GRAN. Wooden rails, steel plates. Incidentally, the surprising thing is that the ties, the idea of using ties was there right from the beginning, one of the unsung inventions of railroads. I couldn't find in my research where that was invented.

Senator MOYNIHAN. Probably some poor Irishman. They are the ones who laid them for the next century and a half. A little lost bit of transportation history was the efforts of parliament in Britain in the 18th century to produce a better road. They had the idea that if you widened the rim of the carriage wheel that would produce—at one point the law required the rims to be eight inches wide so that would pack the road down. Well, it didn't do anything of the kind of course. They finally, instead of working from the vehicle down, they worked from the surface up. I guess that was Mr. McAdams' big breakthrough.

Now, sir, having heard that rather dramatic account of what you get for thinking up new things at G.E., Mr. Rosner, we welcome you, sir.

STATEMENT OF CARL H. ROSNER, INTERMAGNETICS GENERAL CORP.

Mr. ROSNER. Thank you, Mr. Chairman, ladies and gentlemen.

It is my pleasure to have the opportunity to address you on the subject of incorporating what is really the enabling technology for this maglev concept. I daresay that probably Drs. Danby and Powell were stimulated by the existence of high field superconductivity to come up with their invention.

This is in fact a technology that also has been around since the early sixties and has certainly stimulated me to look much more broadly for new technology, and in the end led me to leave General Electric and transform myself from an applied scientist into a businessman entrepreneur. Because what it really takes to make these things happen are people who are determined and stick with an opportunity or an idea, not only for as long as they are getting money from the government, but as long as they really believe that a major impact can be made both nationally and even internationally, as is in fact inherent in the technology of superconductivity.

That is what is very often the driving force in making a success or to concede failure.

As far as I am concerned, certainly the Japanese and the Germans seem to have that kind of determination or vision, if you like, in that they have an ability and foresight to implement projects with longer range payoffs when compared with a seeming lack of such vision by U.S. corporations.

In the face of, as was mentioned already, the pioneering maglev activities which originated in this country, both the U.S. and Canada aborted their projects in the mid-seventies.

If at that time the rationale for our decision was the lack of better superconductors in terms of people being afraid that low temperature technology would make people shy away, the most recent breakthrough in higher temperature superconductors should certainly become the needed stimulus to implement the program outlined in S. 1794.

However, I happen to believe that even without this unexpected scientific breakthrough in new superconductors, the technology of magnetic levitation should be pursued vigorously, because it embodies demanding engineering challenges that need to be solved successfully for many applications. Already many aspects of these have in fact been ably surmounted by Japan and Germany in the intervening period.

So the justification for my point of view is that the experience gained by them and the perspectives developed on overall system related problems will benefit other applications of superconductive technology on a much more broad basis, ranging over virtually every important energy and electric equipment based product opportunities.

So they are marching ahead not only with the maglev and high temperature superconductor program, but also with many other applications in the realm of superconductivity which is really the new revolution in both electronics and electrical industry.

We at IGC have fortunately been able to maintain some semblance of U.S. participation in that we design and manufacture the basic key elements necessary for superconductor equipment; namely, the superconducting wire of which I have a sample here in front of me and which I would be happy to give you some samples of, that embodies in fact the exact material that could be used today to demonstrate magnetic levitation.

Senator MOYNIHAN. Is that the celebrated ceramic wire?

Mr. ROSNER. No, this is not the celebrated ceramic wire. This is still the conventional Nb-Ti superconductor. The ceramic wire really isn't necessary to make this maglev concept workable, but the ceramic wire has to be transitioned into a configuration of such a nature, and it is my opinion that ceramic based wire will not be able to be put in this type of configuration for at least 5 to 10, if not 15, years because the complexity of the wire process—this is a large cross section of what the wire has to look like in terms of making it.

Senator MOYNIHAN. Right. But, sir, consider what you just said, 5 to 7 to 12 years. You can reach out and touch that.

Mr. ROSNER. That's why my suggestion is in fact the technology of maglev can in fact be demonstrated and be just as economical

based on the existing wire. We don't need the ceramic wires to make this project viable.

Senator MOYNIHAN. That would fit in with Mr. Welch's estimates. The real costs are elsewhere.

Mr. ROSNER. Exactly, that's correct.

Senator MOYNIHAN. This may be coming, and so much the better.

Mr. ROSNER. The same conclusion is what in fact the Japanese have come to. They are marching ahead with their next project, a 50-kilometer test line, with the existing SC wire technology and magnet technology that is based on a cryogenic system.

We in our company have all the elements of putting that together, the wire technology, the magnet technology, and the cryogenic technology. We have in fact watched with a combination of admiration and awe how especially Japan has used their long-range maglev, fusion and accelerator programs as attractive and visible targets to channel industry's interest and focus it on applications that have much broader applications. So they have in fact been able to build a very competent and increasingly competitive industrial base in superconductivity more broadly, such that they now can lay claim to a level of engineering leadership in having the wherewithal to apply superconductors to many other product areas, including maglev. That's what gives them the advantage that they seemingly have.

It is this demonstrated ability to have the foresight and a broader perspective, including the patience to invest in the future and act in an area that must, by necessity, be subject to government-industry partnerships, as has already been touched on, and most of my remarks in fact address the kinds of side issues that are required to make this project a success.

We still have a lot to learn in this country to have industry work together rather than only compete. It is inevitable that we do this unless we want to ride in foreign built maglev trains that inevitably will criss-cross the country in the far future.

Senator MOYNIHAN. That inevitably will criss-cross the country.

Mr. ROSNER. That's correct. I think that is really the twenty-first century mode of transportation because there is a limit to the extent in which airlines and even highways can accommodate the increasing population levels. We already are overcrowded. Rather than investing in another national highway system which undoubtedly would be the answer, I think we are much better served to in fact substitute what in fact is an up to date system, namely the Magneplane concept originated by Drs. Kolm, Powell, and Danby.

In fact, also, only a few days ago did I listen to a presentation by Mr. Kyotani at the World Congress on Superconductivity in Houston which outlined futuristic visions and artists' concept of the maglev system. You have a booklet that he also gave me a copy of.

The gentleman, Mr. Kyotani, is the former director of the National Railroads. I also wanted to find out in the context of your committee being responsible not only for transportation, but the Japanese are also pursuing a ship propulsion based upon magnetic superconductor transportation system. So they, by virtue of the fact of having a real understanding of the advantage of superconductivity and magnet technology combination, are looking indeed

at broader transportation issues as well as at broader application issues for superconductivity.

We in the U.S. industry tend to be governed in our decisions by short-term economic realities, sometimes imposed by unrealistic Wall Street expectations, but more often by the fact that efficiency translates itself into near-term economic gains. Therefore, I perceive it may be difficult, although I recognize that with your determination and interest, Senator Moynihan, what I am saying may not happen, in that these large expenditures required, inevitably invite attacks of being economically irresponsible in that the kind of expenditures that might be inherent in this system at the front end is ill advisable. There will be many people who will argue that this is an unnecessary expenditure.

However, I believe that the increasingly rapid pace of high tech commercialization efforts by more and more industrial nations indicates that large scale investments made early on provide a virtually insurmountable market lead that latecomers often find impossible to overcome. So it is extremely important that these decisions be made now because the reality of business is that he who makes the investment first on a large scale continues to have an advantage, just as a front runner is going to be awfully hard to catch by people that are behind because they have to pass him almost with superhuman effort. Likewise, a large scale investment made up front rather than smaller scale investments represent that insurmountable lead that the Japanese through their \$700 million investment perhaps already have, as Dr. Kolm indicated. They have invested up front much more than we have, and we have to really run hard and fast and immediately to try to maintain a position in this area.

I want to make a few more comments relating to entrepreneurially oriented organizations that are already being formed, and as was indicated earlier, really mostly by foreign corporations rather than by U.S. corporations. I think it is absolutely essential that we sustain and encourage the kind of entrepreneurial leadership that already exists in this country, but only in the smaller organizations. It doesn't unfortunately exist in the large organizations.

So we have the paradox that everybody thinks that these kinds of projects can only be handled by large organizations, yet the large organizations don't have the interest or the wherewithal or the long term commitment to make it happen. That's why we are not here in this maglev arena, and that's why the Japanese are there. If you look at the roster of companies in those countries, it is the large corporations that exhibit the long term vision. They have virtually no entrepreneurial cadre. The entrepreneurial energy there is challenged into a collaborative effort between industries to make Japan be the number one country in the world.

So what we seem to have forgotten is that the American public will in fact pay for convenience as the new maglev system would in fact provide, because they are no longer going to be ready to fight traffic to get to the airport or to sit and wait in crowded airplanes, and then travel on overcrowded highways to their final destination.

There is economic proof of that on a smaller scale in the area of prepackaged and prepared food, the public is in fact paying often

five or ten times as much as they could pay if they bought the basic ingredients.

Similarly, I believe if we demonstrate the convenience and rapidity with which maglev in fact can be implemented, I think the American public will make these kinds of systems economically viable.

So if we begin now, we can still exploit the narrow overall advantage we have in superconductive technology, as demonstrated most recently by the successful introduction of superconductive based medical imaging technology, and thereby recapture the initiative in applying superconductive technology to the maglev systems. But I repeat, the emphasis is on *now* because the lead that is being generated is going to be virtually impossible to overcome.

It is IGC's faith in the enormous commercial potential of superconductivity that we are buoyed by the fact that the excitement surrounding the higher temperature of ceramic superconductors have now stimulated a large number of industries and academic institutions involved in electrical, electronic, chemical, ceramic, medical and physical disciplines, to collaborate in a multi-disciplinary fashion. That is what is necessary to make this technology happen as well. That fact bodes well, in my opinion, for the potential future on the part of U.S. industry towards greater global collaboration as well as greater global competitiveness.

In this regard, and before closing, I would also like to mention that I serve as a member of the Board of Directors of the Council on Superconductivity for American Competitiveness. This is a privately funded, non-profit organization composed of private sector entities, as well as universities and government scientists, concerned with the application and development of both conventional and high temperature superconductors. The chairman of this group, Dr. George Keyworth, was unavoidably unable to appear before the committee today, but the Council has made a statement in support of this effort, and that statement is available, and I wish to place it in the record.

Senator MOYNIHAN. Without objection, it will be placed in the record, and you will give our compliments to Dr. Keyworth and to all of you who are involved in this enterprise.

Mr. ROSNER. Thank you.

In conclusion, I wish to reiterate strongly that we at IGC believe that both through our own accomplishments and those overseas from which we now can learn something, that the technology is already here to tackle the challenging technical problems that still lie ahead. The favorable political climate, however, and the financial means must be provided through the concerted action by Congress and the associated industrial commitment over many years in order that this project can be brought to a successful conclusion.

However, at the same time, the vision and approach embodied in this first effort of serious concern about the transportation issue for the 21st century should not deter us from funding and pursuing the necessary R&D related to the overall development of superconductivity which I indicated was the enabling technology for not only this project but also the ship based propulsion system and many other technologies, including the SSC project, which together with S. 1794 and other superconductor initiatives, surely will even-

tually, and sooner rather than later, yield enormous benefits for our Nation and the world.

I thank you very much for the opportunity to express my thoughts on this exceedingly important subject.

Senator MOYNIHAN. We thank you.

Gentlemen, my own failure, I omitted, not knowing how long we might go—the Senate rule is we can't be in session past 1:00. So I am going to have to close.

But I want to ask one quick question. We had a long hearing yesterday on the interstate highway system speed limits, whether you go 55 miles an hour, 65 miles an hour, and that is still something irreducibly dim about our inquiries into automobile safety, the whole question of years after it became, "accidents," which is a prescientific term, became the single largest source of the cause of death between age 1 and 38, we never have had four competent scientists working on the subject, but there are irreducible problems of collision in a system where you put motor vehicles into the hands of a huge population. You assume 80 percent of the population over 21 will drive and will drive indefinitely, and you are going to have difficulties.

There surely are some aspects of just plain safety in transportation that come out of a system of this kind, wouldn't you say, Dr. Gran?

Dr. GRAN. Yes, most definitely, but those issues can be studied, understood, and resolved I believe. I don't see any major problem associating with—for example, one of the trains breaks down and he is in front of you, that can be sensed and the whole system can be brought to a halt.

Senator MOYNIHAN. I was thinking that the motor vehicle, depending primarily on the operation by individuals, by nearly the full universe of adults, 95 million licensed drivers, is bound to introduce variances in behavior that cannot be efficient. There is an irreducible amount of trouble you are going to have in a system where individuals handle this big machine, this big 19th century machine, with very little training to do so and very little review over 50 years of owning licenses and so forth. This alternative is clearly a more attractive one.

Mr. ROSNER. I think, however, there is another potential barrier that maybe should be addressed early on, and that is since we have become such a litigious society, the liability issues that might arise from something that cannot be foolproof and controlled automatically totally. There will be lapses because since there are human beings involved, human beings are likely to have lapses, as we all know.

Senator MOYNIHAN. As we all know.

Mr. ROSNER. This system can be made virtually failsafe. But to convince people to get started and to in fact take the risk of starting up such a system both nationally and in the various States, I think one has to resolve the issue of potential liability. It will never happen, there may never be a single suit because the system, I believe, it can be in fact made foolproof. However, that question has to be laid to rest early on. So it is very important that in your deliberations and considerations that issue is in fact recognized, addressed, and hopefully solved.

Senator MOYNIHAN. Very nicely said. This was a very good hearing. I hope this is an important hearing. I think you heard, Senators Reid and Graham are immediately interested, their States are interested. I think California will come along. Senator Stafford was here, and we have had the staffs of all of our committees.

I want to make the point, and I want to thank each of you, and perhaps especially our applied practitioner, Mr. Welch, for making the point that we are talking about a major public works effort that extends the work on our interstate highway system. That's the unanticipated benefit of—I guess it all began at General Motors' Futurama in 1939 at the World's Fair. But without knowing it, we have created the infrastructure that gives us an opportunity for—we took a 19th century mode of transportation and we've provided the system for, as you said, Mr. Rosner, our twenty-first century mode of transportation.

It is different. It is not a rail system, it is not a railroad. This is something entirely new, and it is an effort that inextricably involves the rights-of-way of the interstate system.

So I am going to close this hearing with an expression of great gratitude to all the witnesses and to the staff who have made it possible. It is going to be a test of us. We are going to test an awful lot of our systems at one time, whether we end up moving around on Japanese vehicles using principles that were developed in Brookhaven in the 1960's. I don't want that to happen, and I don't think it should.

Thank you all, gentlemen.

[Whereupon, at 1:05 p.m., the subcommittee was adjourned.]

[Statements submitted for the record follow:]

Testimony by Henry Kolm, Ph.D.,
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and
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presented to the Senate of the United States,
Committee on Environment and Public Works,
Subcommittee on Water, Transportation, Infrastructure.

at a hearing on the potential of maglev technology
to utilize existing interstate highway rights-of-way
on February 25, 1988, at the Dirksen Senate Office Building

SUMMARY

EXISTING INTERSTATE HIGHWAYS ARE OUR ONLY RESOURCE
for meeting present and future traffic needs
in hubs and along corridors,
where the ground and the air are already congested.
We will never build another railroad or airport!
Highways are our only option!

THE CHALLENGE IS TO CREATE THE NECESSARY TECHNOLOGY
to increase both the speed and the capacity
of existing interstate highway rights-of-way
by a significant amount.

THIS IS THE NEXT REVOLUTION IN TRANSPORTATION
like the railroad in 1830, the automobile in 1900,
and the aeroplane in 1940.

THE REVOLUTION IS INEVITABLE AND OVERDUE
because the technology was invented here in 1970,
shown to be practical in 1974, and dropped in 1975.
New superconductors will make it even more practical.

IF IT HAPPENS IN THE USA,
it will save not only our traffic and environment,
but our economic health.

BUT IF IT HAPPENS IN JAPAN OR GERMANY
it will accelerate our progress
toward becoming a Third World Nation.

WE NEED LEGISLATION TO MAKE IT HAPPEN IN THE USA
by finishing what we started in 1970 and stopped in 75

Existing Interstate Highways: our only resource.

Railroads require rights-of-way which traverse the countryside, virtually without a bend or a grade, cutting every road which crosses their path.

A new railroad from Tampa to Orlando to Miami, for example, would require between 300 and 500 grade crossings, and would carry only one tenth as many passengers as one single highway lane. In most other corridors, things are even worse.

It is not likely that any new railroad will be built in the future.

Nor do we have either air-space or ground-space for new airports. Consider, for example:

The 7.5 square miles of prime space occupied by J.F. Kennedy airport would accommodate a 95 foot wide corridor from Washington to Boston. Newer airports, like Dallas or Toronto, occupy 25 square miles! Where would be put the airports to service any corridor? New airports are as unlikely as new railroads.

THE REAL CHALLENGE

The solution of our traffic congestion is not faster trains or more airports. It is the improved use of existing rights-of-way: the Interstate Highway System which was built by the Eisenhower administration under the slogan: "Safe at Seventy", and which was re-dedicated by the Nixon administration to be "Safe at Fifty-Five".

The challenge is simply to make these same highways "Safe at Two-hundred-twenty", while carrying ten times as many passengers as they do now.

No proposed or even conceivable improvement in railroad technology is capable of meeting this challenge! Nevertheless, the challenge can be met. And it can be met in the near future!

THE FOURTH REVOLUTION IN TRANSPORTATION IS OVERDUE

... because the technology to meet this challenge was invented twenty years ago. This revolution will at least match the last three such revolutions: the railroad in 1830, the automobile in 1900 and the aeroplane in 1940.

If it happens here, it will restore our lost leadership in the transportation industry, and the genuine security which comes from economic health.

If it happens elsewhere, it will accelerate our decline into the insecurity of a third world nation.

The economic health and security of our country may well depend on whether we can make this revolution start here. It may be our last chance, or it may not. But it is a chance we cannot afford to ignore, as we have been doing these past thirteen years.

THE WINNING CONCEPT

The revolution did in fact start here. It started in the late sixties, when three groups independently discovered the magnetic analog of aerodynamic flight: magnetic flight, or levitation by induced repulsion. Let's call it "repulsive maglev" for short.

A permanent magnet floating above a spinning aluminum plate may seem unfamiliar to most of us (electrical engineers included), but it is every bit as natural as a paper dart floating through the air, or a wheel rolling along a highway. And it can go a lot faster than either!

One of the three American groups which discovered repulsive maglev actually pursued the discovery to the point of inventing a practical transportation system, which they called the "Magneplane". It was the group at the Francis Bitter National Magnet Laboratory, at the Massachusetts Institute of Technology, (MIT Magnet Lab for short) which I had the honor of leading.

With support from Industry and the National Science Foundation, we designed a magneplane system and built a 1/25 scale model, which operated beautifully on a 400 foot long track at the Raytheon Laboratory in Wayland, Massachusetts. You may have seen it in one of several NOVA features, or read about it in the papers or in the Scientific American.

Then abruptly, on February 9th, 1975 the Office of Management and Budget announced at an international transportation meeting in Phoenix that the US would terminate all support for ground transportation research. We had spent a total of four years and one million dollars, one third of it from private industry.

AND LOSING THE NATIONAL INITIATIVE

Nor was this the end of the infamy. The Nixon administration then closed the high speed test facility in Boulder, Colorado, which we had just finished building at a cost of 32 million dollars, and sent Volpe, the Secretary of Transportation, to be Ambassador to Italy. His successor, Brinegar, then closed the newly built Cambridge transportation laboratory and continued dismantling our transportation research effort.

Groups in Japan and Germany, however, didn't stop. The Japanese spent seven hundred million dollars pursuing the magneplane idea, but it turned into just another railroad which can only go in a straight line. The Germans spent about half as much, until they ran out of ideas and stopped. The British, meanwhile, built a low-speed, attractive maglev people-mover which has been carrying passengers to the Birmingham airport at 22 miles an hour for three years, and making money in the process.

And here in the United States, we spent thirteen years wringing our hands about the national debt, the trade deficit and the transportation crisis, while we admired all the media reports about Japanese and German maglev transportation break-throughs! The American origin of magnetic flight was forgotten. Even the administrator of the Federal Railroad Administration admitted never having heard of magneplane, at a congressional hearing in April 1987.

Not only have we lost our position of leadership in transportation technology, we have even lost our ability to evaluate it! Our present generation of engineers are transportation-illiterate! Their education in the field is thirteen years obsolete! When the City of Las Vegas wanted expertise to judge a German maglev proposal, they had to turn to a Canadian firm for advice! (And it was bad advice they got).

It seems ironical that a Nation which can afford to spend 3.5 billion dollars to build a Superconducting Supercollider can't afford ten million a year to maintain its leadership, or for that matter its engineering literacy, in transportation technology!

THE OPPORTUNITY OF SUPERCONDUCTIVITY

We hail the recent advances in superconducting materials as an opportunity not to be missed. Yet in over a year of excitement, we have not as yet provided one dime of support for magneplane, or for any other application for that matter.

What funding we have managed to re-allocate, has gone exclusively into a sterile effort to develop materials for which no market exists, nor will exist for another decade. We have forgotten that the same fiasco happened when practical superconductors were first discovered in 1960.

I have made this point as eloquently as I can before more than six high level policy planning groups in the Department of Defense and the Department of Energy, to which I was invited during the past year, but to no avail.

I have offered to build a one sixth scale magneplane demonstration system on the Mall in front of the Smithsonian in three years for ten million dollars, but the proposal evoked more amusement than interest. Meanwhile we continue to fall farther and farther behind our overseas competitors.

The Magneplane Concept

Magneplanes fly several inches above an aluminum trough, containing no motor, only superconducting magnets, resiliently supported by their own magnetic image, free to bank like an airplane and propelled by a travelling magnetic wave which is generated by wires in the guideway.

The travelling wave is synchronized with the vehicles by wayside transformers linked to a central computer which controls the system and ensures separation, permitting vehicles to travel at very close spacing.

Vehicles start and stop on retractable wheels, lift off at about 30 miles per hour, and carry 100 passengers non-stop to their destination. All stops are made off-line.

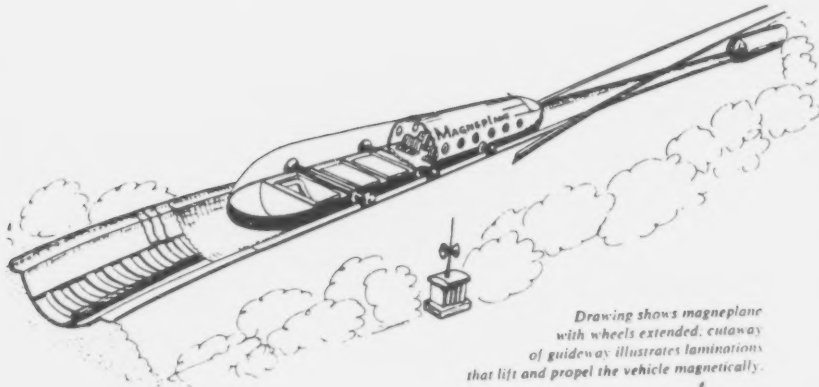
MAGNEPLANE ARTICLES FROM THE 70s ARE APPENDED

Scientific American 1974,

IEEE Trans Mag 1972,

Cryogenics 1975

for those who want to dig deeper.



FEATURES WHICH MAKE MAGNEPLANE HIGHWAY-COMPATIBLE

Magneplanes travel several inches above an aluminum sheet metal trough, free to bank like an airplane. They are supported by a soft cushion of magnetic field, at about one third the pressure of an automobile tire. They resemble a large bobsled more than a train. The guideway trough is light enough to be supported by inexpensive masts.

By combining a climb with a turn, Magneplanes can negotiate a 40 foot overpass without passengers leaving their seats, using less than a half mile of ramp if need be (a chandelle maneuver).

Magneplanes can travel safely at very close spacing, since all vehicles are coupled together electronically. They are loaded and unloaded off-track to make this possible. Thus each magneplane takes its passengers to their destination non-stop or one-stop, like an airliner.

And Magneplane needs only 6 megawatts of wayside power, used twice each minute, instead of 60 megawatts used twice each hour. Here are the differences between trains and magneplanes:

train	magneplane
heavy train	light fuselage (737)
1,000 psgrs, twice/hour	100 psgrs, twice/min
10-stop trips	non-stop or 1-stop trips
cars hard-coupled	electronically coupled
large towns only	can serve many small towns
on-line loading	off-line loading
100 mph	200 mph plus
60 megawatts wayside	6 megawatts wayside power
engineer-controlled	central computer controlled
high pressure tracks	low pressure trough
hard rail contact	soft cushion, inertial path
fixed bank	self-banking
limited bank, grade	maneuverable guideway
vibrations, noise	only air noise
active (powered) vehicle	passive (unpowered)
needs a 30 ft sq tunnel	fits in a 14 ft tube
needs many grade crossings	rides overhead on masts

THESE ARE THE ADVANTAGES WHICH MAKE MAGNEPLANE INEVITABLE
MAGNEPLANE IS GUIDED FLIGHT

Testimony by Henry Kolm, Washington, Feb 26, 1988

page 7

lift-off occurs at about 20 to 30 miles per hour

lift force is soft, but stiffens as contact is approached

THE FASTER YOU GO, THE LESS ENERGY IS NEEDED FOR LIFT

at 224 mph, aerodynamic drag is twice the magnetic drag

at 224 mph, wayside power required is only 6 megawatts, one tenth the wayside power of a railroad, at six times the passenger handling capacity.

Propulsion is produced by a simple meander winding at the center of the guideway trough. It generates a travelling magnetic wave when energized with three-phase AC current. The magneplane just rides this wave like a surfboard.

The AC current comes from special wayside transformers (cycloconverters) located a mile apart and linked to a central computer. These transformers synchronize the travelling wave with the travelling vehicle on the basis of position information transmitted by the vehicle. They also control the speed of every vehicle, and maintain separation between vehicles.

Wayside transformers also serve as shock absorbers, by damping oscillations of the vehicle. They do this by adjusting the phase and thus the vertical and lateral force of the travelling wave.

More details will be found in the appended articles.

Testimony of Dr. James R. Powell* and Dr. Gordon Danby**
on "The Potential of Magnetic Levitated Transport
in the United States"

BACKGROUND

In 1966, we published the first work, ASME-66 WA/RR-5 "High Speed Transport by Magnetically Suspended Trains," copy attached. This sparked great interest, both in these United States and abroad, and inspired many groups to start programs.

We have continued to work on magnetic levitation. Our published inventions include, besides the original concept for a superconducting magnetically levitated train, the null flux suspension and the linear synchronous motor (LSM). These concepts are used in the superconducting magnetically levitated train system demonstrated by the Japanese National Railway (JNR). We obtained the pioneering U.S. patent on superconducting magnetically levitated trains (Patent Number 3,470,828).

Over the years, we have freely provided details about our work to various magnetic levitation efforts including programs in the U.S. and Japan, Federal Republic of Germany, and Canada. Following our first paper in 1966, there was initially a strong program in the U.S., with participation by Stanford Research Institute, Ford, Massachusetts Institute of Technology and others. However, the U.S. program withered away after a few years, due to lack of government direction and support.

The strongest and most sustained program has been the Japanese. During the first several years of their effort, we were frequently visited by high level representatives from JNR and Japanese industry and universities. In our discussions of magnetic levitation and propulsion designs, we were impressed by their commitment and engineering excellence. As their program matured, contacts inevitably became less frequent. However, we have maintained contact with Dr. Kyotani, the Research Director (now retired) of JNR, who was responsible for the Japanese program and who has always graciously credited our contributions to magnetic levitation.

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NEEDS AND GOALS FOR MAGNETICALLY LEVITATED TRANSPORT

The present U.S. transport system, which is principally based on cars and airplanes, is losing capability to rapidly, efficiently, and safely move people. The system is nearing saturation -- delays of hours are common on airplanes (the "scheduled delay") and expressways are jammed, making commuting in effect a second job.

These problems will get worse, not better. Automobile traffic continuously increases, but there is no room for new highways; more airplane flights vie for a fixed number of takeoff and landing slots.

Magnetically levitated transport can dramatically improve U.S. transport capability. A single line of track, for example, could easily carry one hundred thousand people per day, at speeds of 300 miles per hour, with an energy cost far below that of automobiles and airplanes. Delays should be rare, and the system unaffected by weather. Environmental impact will be minimal -- there is no pollution (the trains are electrically propelled), noise is practically eliminated (no wheel on rail contact) and land use is less than highways or railroads.

Besides passengers, magnetically levitated trains can efficiently and at low cost carry freight, autos, and other goods. Manufacturing centers can be directly connected, reducing transport time and cost. The energy cost per passenger-mile will be considerably less than with present transport systems, and will not require oil-based fuels.

The major goals for magnetically levitated transport should be:

1. Safety
2. Affordability
3. Flexible right of way siting
4. Capability for multi-purpose use

Safety is a paramount goal. Our work has aimed at magnetic levitation designs that are highly reliable and incapable of failure. Redundant and backup train magnets and cryogenic system make it impossible for any component malfunction to cause failure of levitation. The null flux suspension is extremely stable -- an external force much larger than the weight of the train would be required to make it contact the track.

The suspension overcomes any external force in any direction, whether lateral, vertical, roll, pitch, or yaw, and maintains stability and clearance under all conditions.

Using the Linear Synchronous Motor (LSM), trains can be electrically propelled at high efficiency along the track at precisely separated and controlled intervals. The control is inherent; separation between trains is constant even if trains are subjected to different local conditions (e.g. wind forces, grades, etc.) and automatic (i.e. no human or computer control is required). This capability results from the "phase-locking" characteristic of the LSM. Such inherent automatic control allows safe operation at high speed and high traffic density.

The superconducting suspensions have a large clearance between the train and track, on the order of 6 inches (it can be designed larger if desired). An inherently stable large clearance is very important, we believe, for maintaining safety and keeping track cost reasonable. For these reasons, we feel that the unstable attractive force suspension approach, in which servo-controlled magnets must maintain a clearance of only 1/2 inch, is less desirable than the superconducting magnetic suspension.

Finally, we believe that it is prudent that passenger exposure to stray magnetic fields from the train suspension magnets be minimized. Our goal has been to keep passenger exposure at normal Earth background field values (~1 gauss) through appropriate design of the train magnet system and use of local shielding.

Affordability is the second paramount goal. The principal cost component in any magnetically levitated transport system will be the track. Although there has been much excitement about high temperature superconductors and their impact on the feasibility of magnetically levitated transport, it is track cost that is the principal barrier, not the cost of the superconducting train magnets. Present superconducting magnets are cost effective for magnetically levitation, even at liquid helium temperatures.

Our recent work has convinced us that large reductions in track cost are possible, without compromising safety, stability, and performance. Using improved design approaches, components can be mass produced and assembled with a minimum of field construction and cost. A two-way track cost of approximately 2 million dollars per mile (exclusive of right of way) is a very attractive goal, and would allow widespread use. Such a track cost appears possible with a proper design approach.

Flexibility in Siting - One must avoid "highways in the sky," that is, the equivalent of building a second deck above the Long Island Expressway. Not only will such track systems be very expensive, but they require massive land-use, severely limiting siting locations.

A magnetically levitated transport system should be siting-flexible, capable of using existing rights of way (either auto or railroad) and co-existing with them. It should be compatible with tunneling, cut and fill, surface type and (where required) elevated (pylon) type construction. Appropriate barriers (e.g. fencing) may be needed to limit access.

Capability for Multi-Purpose Use - A U.S. high speed magnetically levitated transport system should be capable of evolving to meet multi-purpose applications, such as the rapid movement of heavy freight at high energy efficiency. This could also include auto-train systems that could help offset the lack of public transport infrastructure for the many U.S. locations where point to point transport is not sufficient.

TECHNOLOGY DIRECTIONS

1. The JNR using a well planned and broad based application of our original concepts have demonstrated multi-vehicle trains that successfully carry people at high speeds. The technical components are at hand to build first generation commercial systems.

2. A U.S. program should leap-frog the JNR technology, going beyond it to track and vehicular designs that will be cheaper and can, when desired, carry heavy freight in an expanding and evolving system. Our recent studies indicate that this is practical while preserving the features of full magnetic shielding, large clearance and low energy consumption.

3. There are two other approaches proposed for magnetic levitation.

a) Germany is pursuing small clearance (1/2 inch) attractive force magnetic levitation. This is inherently unstable (the train magnets are strongly attracted to the rails above them) and must be controlled by rapid servo adjustment of the magnet current.

It is our belief that this approach is not practical for high speed (200 to 300 mph) transport. This attractive force suspension could theoretically be a quiet "subway," providing an alternative to rubber tired wheel on rail cars that would operate at relatively low speeds.

b) Various authors have studied the so-called conducting sheet repulsive force suspension. In this concept, relatively large superconducting train magnets inductively interact with an continuous conducting aluminum sheet that extends below the train, generating a magnetic suspension force. This approach has a number of drawbacks.

- (1) The suspension is weak, not strongly inherently stable.
- (2) It has high magnetic drag and high energy consumption. (Lift to drag ratio is lower than that of airplanes).
- (3) Track costs will be high, due to the large amount of materials and field construction required.
- (4) It is harder to magnetically shield the passenger compartment.

The Japanese and ourselves chose not to follow this approach, and have concentrated on the more promising inductive loop type suspensions.

4. The new high temperature superconductors have correctly generated great enthusiasm, in part out of technical interest and in part out of belated concern for technical competitiveness. They indeed have very attractive possibilities for levitation.

It must be emphasized however that, compared to various other applications of superconductivity, the levitated train system can function economically and reliably with present day superconductors. The use of the new superconductors is desirable, but not necessary, for developing a working system.

GOVERNMENT POLICY AND INITIATIVES

We believe that a U.S. program on magnetically levitated transport should have the following features:

1. Industry oriented
2. Near term application ("fast track" program)
3. Emphasis on technical and economic practicality
4. Competitive "horse race" approach in initial stage
5. "Leap frog" Japanese and FRG technology
6. Government research on long range, advanced technology

Industry Oriented, because the necessary technical expertise already resides in U.S. industry. If properly directed, it can quickly develop practical, economic systems.

Near Term Application, because it efficiently uses resources, focuses on real needs, and forces us to catch up with foreign systems.

Emphasis on Technical and Economic Practicality, because there is no point in developing technology that cannot be used. The U.S. goal should be to minimize cost and maximize technical simplicity, so that magnetically levitated transport can grow to be widely used, rather than be an expensive "white elephant" kept alive only by government subsidy.

Competitive "Horse Race" Approach, because it allows the best approach, both technically and economically, to quickly emerge. Using an open competition solicitation, design study contracts could be awarded to promising proposals by various industrial teams. These initial studies would take on the order of one year. The designs would then be evaluated, taking into account how well they were analytically and experimentally validated as well as their technical and economic attractiveness. There then would be a down-select of designs and teams, with the surviving approaches carried into more detailed development and testing.

In such a "horse race," it is important to have highly qualified, technically aggressive government administrators and contract monitors who will actively challenge industry to come up with innovative, faster, and cheaper designs.

"Leap Frog" Japanese and West German Technology, because it is pointless to duplicate their systems. The U.S. should develop better approaches, particularly with regard to track cost. Actually, right now it is to our advantage to be starting from behind, since foreign systems are to a great extent "locked in" to their technologies and cannot readily change. As emphasized above, however, the U.S. should not pursue dead-end approaches that do not provide a clear improvement. Realistic assessments need to be made; if proposed designs are not clearly better than the already proven Japanese and German systems, they must be dropped.

Government Research on Long Range Technology, because long term, high risk/high payoff efforts fit best in government laboratories. This could include work on high temperature, high current superconductors and ultra low drag trains, for example. The optimum support level for this fraction of a U.S. magnetic levitation program is probably about 10 to 15% of total funding.

IMPORTANCE OF THE U.S. MAGNETIC LEVITATION PROGRAM

It is very important to begin a U.S. program on magnetically levitated transport as soon as possible in order to remain competitive. If a strong program is not in place within the next few years, the U.S. will lose its chance of overtaking foreign efforts. Their system will evolve, becoming simpler and cheaper, closing the door to opportunity. The U.S. will inevitably have to buy systems rather than develop our own.

If we start now, we can develop better approaches that can be used in our country to improve our transportation system and provide a better quality of life.

TESTIMONY OF DR. GORDON DANBY
HEARING ON USE OF FEDERAL HIGHWAY RIGHTS-OF-WAY FOR
HIGH SPEED TRANSPORTATION SYSTEMS

FEBRUARY 26, 1988

My colleague, Dr. James Powell, and I wish to express our thanks for the opportunity to discuss high speed magnetically levitated transport systems with the members of the Subcommittee on Water Resources, Transportation and Infrastructure on Water Resources, the United States Senate Committee on Environment and Public Works.

1. We strongly support the timeliness and importance of your initiative. We have been at this work since 1960. In fact, our original patent has expired. This is our off and on "hobby" project.

2. I will emphasize only a few points in support of our written statement.

3. The Japanese National Railway (JNR) has successfully demonstrated magnetic levitation and propulsion of multiple car trains. They carry passengers and have performed extensive experiments for years now, such as deliberate track dislocations at very high speeds. They have done an excellent job-- intelligent and thorough.

4. For projects with large scale implications, the go ahead to funding is always very difficult: many questions arise, does it basically work or is it a technical boondoggle? This has been

- 2 -

put to rest for Maglev by JNR, at least at the fundamental level. A U.S. program can start from this achievement and move on to second generation ideas and applications more appropriate to the U.S. situation.

5. How does it basically work? Superconductivity (SC) permits very strong but lightweight magnets to be distributed along the vehicle. On the ground there is only a track of ordinary copper or aluminum conductors to levitate and propel the vehicle. Current is induced in the track only when the train magnets move directly overhead.

6. The Linear Synchronous Motor (LSM) works like household motors, except that the magnet poles move in a line rather than in a circle. Because the SC magnets are so strong, only low current windings in the ground are required for strong propulsion forward, like a wave acting on a surfboard. The speed is automatically determined by the A.C. frequency and the spacing of the magnets. If the vehicle falls slightly behind, it is pushed harder; if ahead, the push is weaker.

7. LSM propulsion, like levitation, is inherently stable, making for great simplification and enhanced safety.

8. Magnetic levitation involves potential energy. There is no fundamental law of nature that says energy must be dissipated. In practice for our designs, the losses for levitation are extremely small. Even for propulsion, the energy consumed due to purely electromagnetic causes is very small. Most of the energy consumed is to push the air out of the way. This air drag is independent of the payload carried inside the

- 3 -

vehicle. As a result we have developed design concepts for both lightweight passenger vehicles and heavy freight vehicles.

We make this point because Maglev is usually not considered in the context of freight or mixed-mode transport. We know how to move heavy freight at high speeds with very little energy consumption.

9. The United States is a very large country with diverse transportation needs. There is a great variety of terrain and population density. An evolving Maglev system should ultimately be easily and economically adaptable to varied situations.

Maximum exploitation to the extent practical of existing rights-of-way is highly desirable. For example, a casual observer can see that much of our interstate highway system is straighter and more level than would be required if control of personal discomfort due to forces on the body were the sole criterion of design. It follows that in many locations much greater speeds than are practical for autos could be used before passengers would become uncomfortable from the "roller coaster" effect of going over hills and around corners.

10. Different speeds are possible. Starting and stopping already require variable frequency propulsion currents. In principle some locations could operate at different speeds from others to conform to the realities of available road beds or even length of trip.

11. We have perhaps raised issues which go beyond the scope of any initial utilization of Maglev transport. The first system might be located in a very heavily populated corridor, or might

- 4 -

be between two cities with low population density in between. The first application will probably be basically a people mover.

However, we would urge that the levitation technology chosen for development should be flexible enough in potential application that it is not eventually self-limiting. There are large portions of the country where only a major freight component can justify such systems.

12. A successful revolution in transport with its supporting infrastructure development must be based on significantly increased mobility. Large scale usage requires savings in time and in cost, including energy. This applies to passengers and to freight.

Magnetic levitation can provide high speeds with low energy consumption if highly utilized for passengers or freight. Vehicle costs are modest. Track maintenance should be minimal, in contrast to conventional trains, since reaction forces on the tracks are very low because they are spread along the length of the vehicle.

In closing, it is worth noting that the very large labor costs of properly maintaining conventional railroad track roadbeds have played a very significant part in the deteriorated state of our wheels-on-steel railways.



WRITTEN TESTIMONY OF

LARRY R. JOHNSON
DIRECTOR, CENTER FOR TRANSPORTATION RESEARCH
ARGONNE NATIONAL LABORATORY

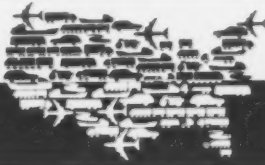
before the

SENATE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
SUBCOMMITTEE ON WATER RESOURCES,
TRANSPORTATION, AND INFRASTRUCTURE

HONORABLE DANIEL PATRICK MOYNIHAN, CHAIRMAN

Washington, D.C.

February 26, 1988



Center for Transportation Research

Energy and Environmental Systems Division
ARGONNE NATIONAL LABORATORY

TESTIMONY OF LARRY R. JOHNSON

before the

**SUBCOMMITTEE ON WATER RESOURCES, TRANSPORTATION, AND INFRASTRUCTURE
U.S. SENATE DIRKSEN OFFICE BUILDING**

February 26, 1988

Good morning, Mr. Chairman and members of the Subcommittee. I appreciate the opportunity to appear before the Subcommittee today to discuss the potential for magnetically levitated (maglev) vehicles as a means of both intercity travel and as a technology option to relieve the growing problem of air traffic congestion.

I am the Director of the Center for Transportation Research, which is part of the Energy and Environmental Systems Division at Argonne National Laboratory. At the Center, we conduct technology evaluations, economic analyses, and environmental assessments of new energy technologies for the transportation field.

During the past several months, we have been examining the potential benefits of high-temperature superconductors as applied to magnetically levitated vehicles and, in a general way, the economic potential for maglev vehicles. The observations that I will make today are the result of this research, which has been sponsored by the U.S. Department of Energy, Office of Transportation Systems.

To best explain how we arrived at our conclusions, I will divide the presentation into four parts:

1. The technical benefits of high-temperature superconductors
2. The current status of maglev research
3. The markets for high-speed maglev vehicles
4. Maglev as a technology option for airlines.

TECHNICAL BENEFITS OF HIGH TEMPERATURE SUPERCONDUCTORS

Although there are about 10 different methods of levitating vehicles, most research has centered on two approaches: (1) use of an attractive force generated by an

electromagnetic system (EMS) and (2) use of a repulsive force generated in an electrodynamic system (EDS). Stated briefly, there are several major differences between the two systems, which are illustrated in Figure 1. The EMS systems use conventional iron-core electromagnets that lift the vehicle as the magnets are attracted towards a ferromagnetic rail in the guideway. Clearance between the vehicle and guideway is extremely small — on the order of 1/2 inch. Because an attractive force is used, the EMS is inherently unstable and requires gap sensors and accelerometers to maintain the required clearance. This system does levitate at all speeds as well as when the vehicle is stopped, and thus does not need wheels.

The EDS, or repulsive, system generates a large clearance (4 to 10 inches) between the vehicle and the guideway, but uses superconducting magnets for efficient maintenance of that clearance. The magnets can interact with either aluminum or multiple-turn coils in the guideway. Because repulsive forces are used, the system is inherently stable; thus the EDS does not need feedback controls, but does require an active damping system for acceptable ride quality. Typically, vehicle must achieve a speed of 25-50 mi/h before the eddy currents generated in the guideway levitate the vehicle; consequently, wheels are needed. Linear synchronous motors are generally the preferred means of propulsion for both the EDS and EMS technologies.

With these differences in mind, it is worth noting that researchers in the U.S., Japan, and Canada concluded that of the two systems, the EDS (repulsive system) offered the greatest promise for commercialization in high-speed applications, principally because the larger clearance provides greater design flexibility and results in a more "forgiving" system that can withstand the rigors of revenue-service operation.

Only West Germany has aggressively pursued the attractive system for high-speed transportation. (Romania is also conducting research into low-speed attractive maglev systems and reportedly has extended that research to high-speed systems.) West Germany's choice seems to have been made on the basis of successful low-speed

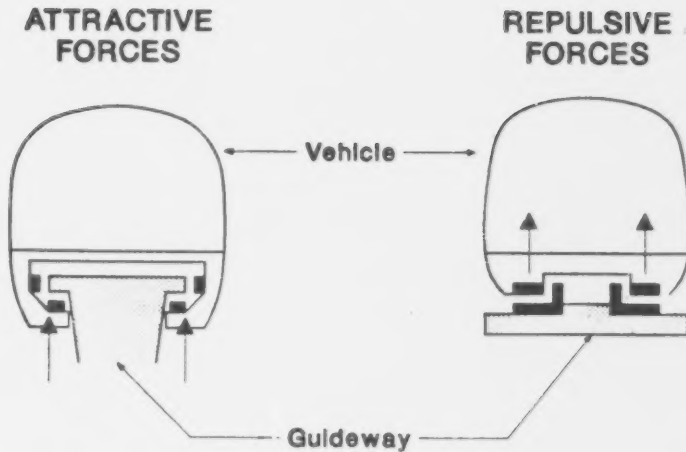


FIGURE 1 Configurations for Magnetically Levitated Vehicles (Adapted from Alscher et al, 1984)

applications that could be demonstrated in high-speed prototype form, as well as the fact that conventional iron-core electromagnets are off-the-shelf technology and therefore closer to commercialization than superconducting magnets. There are strong differences of opinion in the engineering community as to whether the close guideway tolerances (of 4 hundredths of an inch per 40 feet of length) can be economically built and maintained for revenue operation. At this point, I can only say that the issue remains unresolved.

With respect to the repulsive systems generally favored in the U.S., Canada, and Japan, the new high-temperature superconductors offer several advantages, over the present low-temperature superconductors used in prototype EDS maglev vehicles:

- o The new magnets may be less costly because the raw materials for the new superconductors are not expensive. This, however, statement must be

qualified, because the ultimate processing techniques (and associated costs) for the new high-temperature superconductors are not yet known.

- o The new superconductors will have lower cryogenic costs, because they will use liquid nitrogen as a coolant rather than liquid helium. Further, a liquid nitrogen refrigerator or dewar will weigh less and consume less energy. However, the combined cost savings associated with both the magnets and cryogenics are expected to be small -- on the order of 1-2%.
- o Since the guideway represents 60-90% of the total cost of a maglev system, research into cost reductions should examine this area closely. The new superconductors may be able to generate larger magnetic fields. This aspect of greater field strength offers improved design flexibility and perhaps the greatest opportunity to reduce overall system costs through the use of a lighter system.

Larger fields may mean that the amount of sheet aluminum needed in the guideway to induce the eddy currents could be reduced significantly. Because the aluminum would run the entire length of the guideway (several hundred miles), this cost saving could be the most substantial. This, is a complex issue, however, that involves trade-offs in magnet size and track clearance.

- o The new superconductors should also make possible a lighter and less expensive method of shielding the passenger compartment from the magnetic fields generated by the levitation magnets.

- o Finally, system reliability for revenue-service operation should be improved because the new superconducting magnets would operate well below the critical temperature (e.g., operating at 77 K when the critical temperature is between 90 and 110 K with the newest materials). Excursions of a few degrees would not cause the superconducting magnets to develop resistance in the coils. Moreover, the use of a familiar coolant such as liquid nitrogen would simplify day-to-day operation and further enhance the system's reliability.

It is important to keep in mind that the new high-temperature superconductors are an *enhancing* technology, not an *enabling* technology. Maglev vehicles can be levitated and propelled with low-temperature superconductors or even without superconductors. But the high-temperature materials will have a favorable impact on the cost side of the equation. Because transportation systems are sensitive to both costs and revenues, any maglev research program ought to exploit the benefits of these new materials.

As a final note on the potential of the new high-temperature superconductors, development of materials is likely to be evolutionary; one cannot count on breakthroughs. Materials must not only improve in the transition temperature, but just as important, they must achieve higher transport current density and mechanical strength. In general, the lower the threshold values for these critical parameters, the earlier that commercial applications could be found. Table 1 shows the threshold requirements for current density and field strength for some large-scale applications frequently mentioned as possibilities for the new superconductors. The field strengths are relatively modest for all of the applications. The current density requirement for maglev systems, though, is the lowest of the listed applications, when the present designs are compared.

TABLE 1. Design Goals for Selected Large-Scale, High Temperature Applications

Application	Current Density (1,000 amperes/ sq. cm)	Field Strength (tesla)
Maglev Systems	1	2-3
Generators (300 MW)	3	2
Magnetic Separators	3	2-5
Transformers (1,000 MVA)	10	.3
Transmission Lines (10,000 MVA; 230 kV)	23	<1
Superconducting Magnetic Energy Storage Systems (5,000 MWh)	60	1-5

Source: Adapted from Wolsky, A.M., et al., *Advances in Applied Superconductivity: A Preliminary Evaluation of Goals and Impacts*, Argonne National Laboratory, ANL/CNSV-64 (1988).

Therefore, new high-temperature superconductors may be available for maglev systems before they meet the threshold requirements for some other, larger-scale applications.

CURRENT STATUS OF MAGLEV RESEARCH

Active, ongoing research in magnetic levitation has been conducted around the world for the last 25 years. It is worth briefly noting the extent of that research, because the commitment to R&D in this field is one indicator of the potential for eventual and successful commercialization, at least from the perspective of those funding the research.

Pioneering work began in the U.S. with a feasibility study of a high-speed test facility using rocket propulsion at the Sandia National Laboratory in 1964. By 1966, a repulsive levitation concept had been developed at Brookhaven National Laboratory. Major work began in the U.S. when MIT initiated maglev research in 1969 with support

from the National Science Foundation. By the early 1970s, two maglev studies were sponsored by the U.S. Department of Transportation: one at the Ford Motor Company, and the other at the Stanford Research Institute. Both the attractive and repulsive systems were evaluated in the DOT studies; Ford and SRI concluded that the repulsive system had greater technical merit. The MIT work culminated in a working scale-model EDS system using superconducting magnets. Federal funding for all high-speed U.S. maglev research was terminated in 1975, a decision based on budgetary considerations rather than on technical feasibility.

Maglev research has been most aggressively pursued in West Germany and Japan. Both countries examined the attractive and repulsive systems; for high-speed use, West Germany eventually focused on the attractive system, while at about the same time Japan began to concentrate on the repulsive system.

Japan has been active since the 1960s and has spent an estimated \$700 million through 1985. Their work has evolved through several designs, from an "inverted T" guideway with two different prototype vehicles to the present "square U" design that also has progressed through two different prototype vehicles. The Japanese have a four mile test track, and a 20-mile extension is planned. More than 25,000 miles of tests were conducted on the first prototype. They are presently testing the MLU-002 prototype - a 17-ton, 44-passenger vehicle with a design speed of 300 mi/h; two years of tests are planned. Following successful completion of those tests, a 30-mile system is planned between Narita International Airport and downtown Tokyo. The present highway connection is so congested that travel times of 1 1/2 hours are typical. The maglev system will be designed to complete the trip in 10 minutes. This corridor is currently planned to begin revenue service by 1992. The next corridor planned is between Tokyo and Osaka, a 350-mile link.

West Germany has pursued maglev research since 1969, committing \$400 million through 1985. West German researchers have a 19-mile test track and are presently

testing their sixth prototype design -- the Transrapid 06, a 102-ton, 98-passenger vehicle. In December 1987, it was tested at a speed of 252 mi/h. More than 15,000 miles of tests have been accumulated on the Transrapid 06. The Germans have also been innovative in research to automate the fabrication of guideway components, thus addressing the high-cost portion of the system. They are aggressively pursuing the Los Angeles-Las Vegas franchise and their technology (over the competing French TGV steel-wheeled, high-speed train) is favored by the City of Las Vegas.

The Canadians also had an active maglev research program between 1968 and 1984. The impetus for their research was to provide high-speed, ground transportation in the 370-mi corridor linking Toronto, Ottawa, and Montreal. Their original system design called for a 100-passenger vehicle with a cruising speed of 300 mi/h. The Canadian design is an EDS levitation system with propulsion by a linear synchronous motor. Work essentially ended in 1984 due to budgetary constraints.

Although details are difficult to obtain, magnetic levitation studies have been underway in Romania since 1976. By 1979, a 3-ton test vehicle (the Magnibus 01) had been built. Research has been conducted on both low and high-speed applications. The high-speed versions have a design speed of 250 mi/h. Little has been reported on this work since 1984, when the Magnibus 02 -- a 36-ton, 64-passenger, high-speed vehicle -- was being designed. The Soviet Union reported is also engaged in maglev research, but details of those efforts are even sketchier.

In terms of research activity, West Germany and Japan are by far the current leaders. Both countries are aggressively pursuing the U.S. as markets for their technologies. It is interesting to note that the Office of Technology Assessment* concluded that "U.S. maglev research was on a par with similar research programs at the time the U.S. Government canceled it in the mid-1970s". Now, one can conclude that the U.S. ranks fifth or sixth (behind Romania) in maglev technology.

*OTA, *U.S. Passenger Rail Technologies*, Washington, D.C. 1983.

THE MARKETS FOR HIGH-SPEED MAGLEV VEHICLES

Despite the lack of a Federal presence in the research for maglev technology or any support for high-speed ground transportation systems since 1975, regional interest has developed in about a dozen states. Recognition of increasing air traffic and highway congestion, plus a desire to maintain a balanced transportation system have been the principal reasons that states and cities have begun to reexamine the viability of rapid, intercity ground transport. These regions include Florida, California/Nevada (particularly the City of Las Vegas), the Northeast Corridor (Boston-New York-Washington), Pennsylvania, upstate New York, Michigan/Illinois, Ohio, Texas, Missouri, Washington state, Georgia, and New Mexico. The range of interest varies from favoring the maglev technology to upgrading the existing railroad technology, but for several of the corridors maglev is either the preferred technology or on the short list of preferred alternatives.

In our analysis of the potential markets for maglev, we concluded that air traffic congestion was a problem of national scope, not just a regional phenomenon. As shown in Figure 2, the Federal Aviation Administration is forecasting that air traffic will nearly double by the year 2000 over 1985 levels, which in turn represented a doubling over the

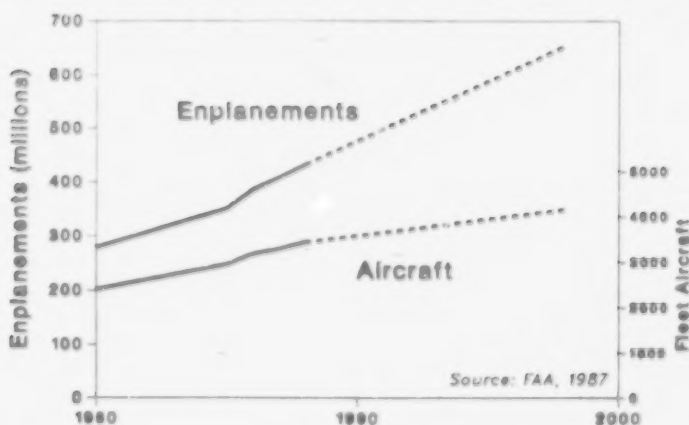


FIGURE 2 Forecasts of Major Air Carrier Activity (Source: FAA, 1987)

1970 levels. The accelerated growth in air travel has already produced excessive delays at the nation's major airports. This problem of increasing congestion is not simply a matter of frustration but represents real costs to both passengers and airlines.

Precise calculations of the costs of these delays are not possible because each individual or company has a different value of time, but rough estimates of the total cost of air traffic delays have been made. The FAA determined that cumulative costs of air traffic delays during 1985 were \$1.8 billion for the scheduled airlines, which was equivalent to about 7% of their total direct costs. Furthermore, these delays cost airline passengers an additional \$1.1 billion in lost time. The total cost to both scheduled air carriers and their passengers thus was nearly \$3 billion for a single year. Because these costs apply only to scheduled air carriers, the effects of congestion for all air traffic delays (including general aviation and commuter air traffic) are consequently underestimated.*

Much of the delay associated with the increase in air travel occurs at the nation's major hub airports. Figure 3 shows that 11 airports already have in excess of 3 million hours of passenger delay per year. Chicago and Atlanta, as might be expected, lead the list. All three of the major airports serving New York City are also included.

Without the addition of major increases in capacity, the number of airports with this level of excessive delay will double in only 10 years. Airports serving smaller metropolitan areas, such as Salt Lake City, Washington D.C., Orlando, Miami, Houston, Detroit, Minneapolis, and Phoenix will be added to the list of facilities with extreme delays. Figure 4 indicates the levels of delay that can be expected by 1996 for the 22 airports forecast to experience significant congestion. Similar data also have been developed to show the congestion effects in terms of aircraft delays. The pattern is the

*Airport Capacity Enhancement Plan, U.S. Department of Transportation, Federal Aviation Administration, DOT/FAA/CP-87-3, 1987.

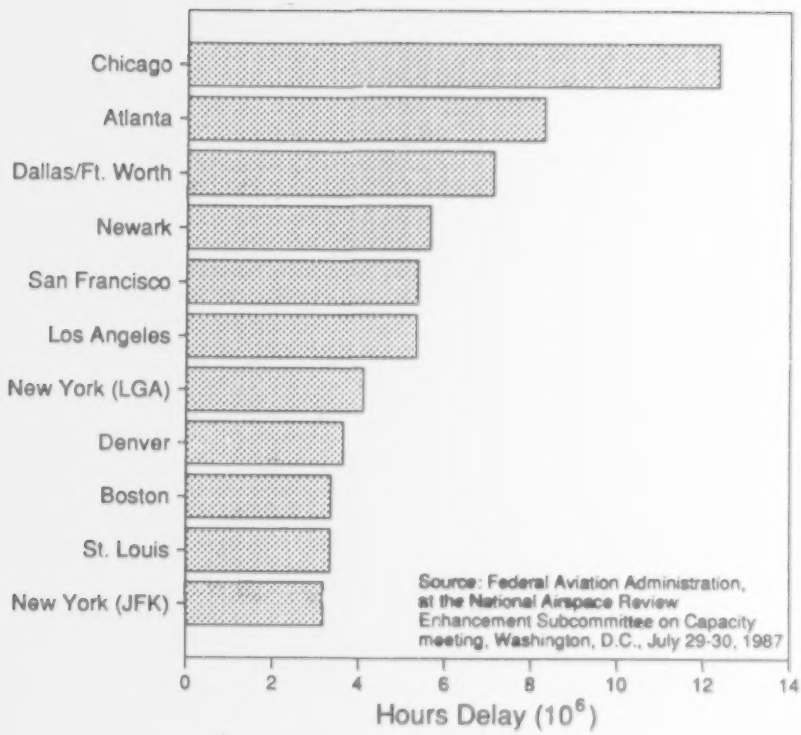


FIGURE 3 Airports Exceeding 3 Million Hours of Passenger Delay in 1986

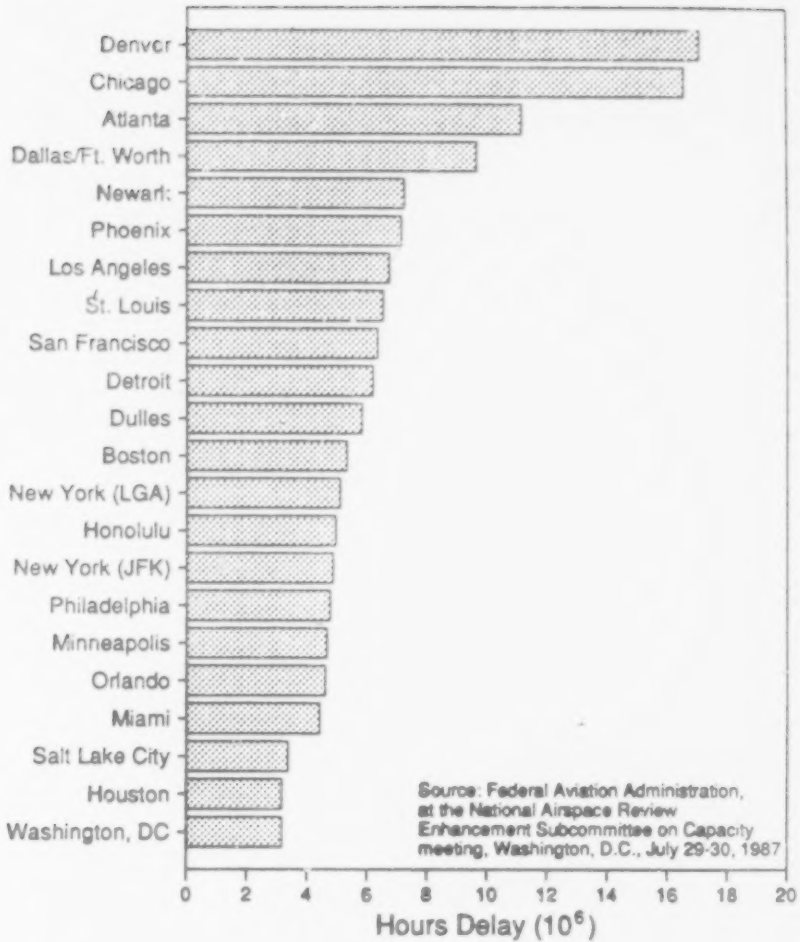


FIGURE 4 Airports Forecast to Exceed 3 Million Passenger Hours of Delay in 1996, Assuming No Increase in Capacity)

same, except that even more airports are affected, at such communities as San Jose, Raleigh/Durham, Las Vegas, Seattle, and Nashville.

This rapid growth in passenger enplanements will mean that some methods to increase the capacity of the system must be utilized. Among the alternatives being considered or already in place are reducing the horizontal separation between aircraft, using larger aircraft, rationing take-off and landing slots at airports, building new airports, or substituting an alternative technology for some air routes.

Reducing separation of aircraft involves a careful analysis of the safety issues and has obvious limits. Airlines are already using larger aircraft, and airports are already limiting departures and arrivals at some major airports. The planning and construction of new airports is a lengthy process (about 10 years), and only the new Denver airport is substantially along in the planning process.

Of the alternatives currently being examined, only the construction of new airports provides substantial new capacity -- unless there are new technologies that could substitute for some portion of the air travel. It is from this perspective that maglev vehicles could provide a realistic option to relieve some of the excessive delays in air travel. However, marketing (as described below) now becomes as important as the technology.

MAGLEV AS A TECHNOLOGY OPTION FOR AIRLINES

Most of the studies that evaluated maglev systems have been conducted as comparisons of maglev with high-speed, steel-wheeled trains. As a result, magnetic levitation has been generally viewed as a train technology, and the term "maglev trains" is frequently used. The analysis has been generally predicated on the assumption that faster travel times from the downtown of one city to the downtown of another city is the goal. But that travel pattern is only one part of the total intercity travel picture. Further, it is not intercity rail systems that are congested, but rather air traffic.

If maglev vehicles were introduced as a train technology between two cities and the competition were viewed by the airlines as threatening, it is quite likely that the airlines would respond with fare cuts and other incentives that have made air transport the predominant common carrier for intercity trips (accounting for 92% of the passenger-miles of travel). Yet, maglev could be offered to airlines as a technology substitute for the short-to-medium-distance (100-500 mi) markets. Major airports, as well as downtowns, could be connected via maglev systems in which most of the routes could use existing interstate highway land or, in some cases, abandoned railroad rights-of-way.

By building networks of maglev systems, around major hub airports, the airlines could retain their familiar hub-and-spoke systems with the maglevs an integral part of the spoke portion. Speeds of 250 to 300 mi/h ensure a logical market niche for maglev on routes of 100 to 500 miles. Trips under 100 miles are likely to be made by automobile, whereas trips significantly greater than 500 miles will continue to be dominated by aircraft. Figure 5 shows a conceptual maglev network in which the long-haul trips are



FIGURE 5 Conceptual Hub-and-Spoke Systems Using Maglevs

still made by aircraft and maglev systems begin to form networks around the major hub airports that have sizeable population centers within a radius of 100 to 500 miles.

The capital costs of high-speed maglev systems are difficult to compare to those of existing transportation systems, because maglevs are still in the development stage. However, a few comparisons are necessary to put the relative investments into some perspective. Estimates of maglev systems vary greatly, depending -- as other transportation systems do -- on the corridor. The highest estimates come from Japan, where costs approach \$30 million per mile, reflecting the high costs of land in a country with high population density. By comparison, urban interstate highway segments in the U.S. have exceeded these costs. A reasonable per-mile estimate of maglev capital costs in the U.S. is about \$10 million, with a range of \$5 to \$15 million. This compares to interstate highway construction costs in suburban areas of \$15 to \$25 million per mile and in rural areas of \$5 to \$10 million.

High-speed, steel-wheeled trains have generally been shown to have capital costs up to 30% less than maglev systems. However, cost estimates for the maglevs have been declining as experience with the technology has increased; the Japanese now indicate that their maglev system should cost about 3% less than their Shinkansen bullet train. Light-rail commuter systems are in the range of \$5 to \$10 million per mile for urban/suburban locations. New airports for cities the size of Denver or Miami are expected to cost \$2 to \$3 billion. New aircraft are in the range of \$40 to \$50 million each. From a cost perspective, maglev appears to be a reasonable technology for which the costs should be compared to the anticipated benefits.

A number of benefits can accrue to airlines, aircraft manufacturers, and air passengers. For each short-haul or medium-distance flight that can be diverted to a maglev system, an airline can substitute a longer-haul flight. The short-haul flights use an inordinate amount of fuel in climbing and descending, and fuels costs are still a major component of airline operating costs. Maglev energy consumption would be significantly

less than that of aircraft, and their electrical propulsion system would not have the emissions associated with petroleum fuels. Moreover, because maglevs are centrally controlled, they should have lower labor costs associated with their operation. Consequently, airlines should be able to provide continuing service to existing markets at lower operating costs.

Because maglev vehicles are essentially fuselages without wings, aircraft manufacturers could be the logical industry to build the vehicles. With a cruising speed of 300 mi/h, maglev vehicles can easily be viewed as an aerospace technology, rather than a train technology. The expertise of the airframe industry will be needed. Indeed, if air traffic congestion continues to worsen, the lack of sufficient airport capacity will adversely affect aircraft sales. The maglev system offers manufacturers the opportunity to continue to supply the technology for short- and medium-distance markets. If airlines substitute maglevs as part of their spoke systems, the longer-haul aircraft market can grow without the constraint of congestion from the short-haul traffic. Consequently, the market for larger, long-haul aircraft sales should also benefit.

Passengers should ultimately benefit from maglev technology. Their travel options will be extended, their delays will be reduced (even inclement weather has less of an effect on maglev systems), and they should incur lower costs for their intercity travel.

In recent discussions with other researchers, we have found that the view of maglev as an airline technology is being independently corroborated. In Canada*, maglev is perceived as complementary to airline technology to connect the government center in Ottawa with the two major population centers of Montreal and Toronto. Pennsylvania** is now focusing on the development of a maglev network that would radiate out from the Pittsburgh airport to connect major population centers within 250 miles.

*Personal communication with William F. Hayes, National Research Council of Canada, February 17, 1988.

**Personal communication with Richard Uher, Rail Systems Center, Mellon Institute, Pittsburgh, February 23, 1988.

For the nation, there are additional benefits. Maglevs could extend the useful life of many of the nation's hub airports, postponing -- perhaps for several decades -- the time when new airports must be built. Because maglevs are powered by electricity, there is also the opportunity to divert part of our transportation energy use to nonpetroleum fuels, thereby enhancing the nation's energy security.

Regarding high technology and international competitiveness, concern is growing that while the U.S. is making considerable advances in the basic research in high-temperature superconductors, the Japanese are likely to capitalize on the commercialization of the technology. The U.S. has no assurance of leading in basic research; the recent discovery by Hiroshi Maeda in Tsukuba of a new ceramic (bismuth, strontium, calcium, copper, and oxygen) that is superconducting at 110 K suggests that this field will be extremely competitive internationally. However, there is no point in conducting basic research unless there is an intent to apply the technology. If the U.S. has no large-scale application for superconductor technology, by default the commercialization will go to the country that does. The Japanese have indicated that they will incorporate the new high-temperature superconductors into their maglev vehicles. They will develop the technology to meet needs within their own country, but clearly with an eye toward marketing systems in the U.S. and elsewhere.

Initiating support for maglev technology will provide no assurance that we will dominate its commercialization. But there is reason to believe that we can quickly regain leadership. Many of the pioneers in research when the U.S. led in the technology have maintained an active, if unfunded, interest. They can form the basis for a new effort. But more important, mistakes have been made in technology development overseas -- mistakes that we can learn from. Prominent in what we know now is that a maglev system must employ light weight as a key design parameter to reduce capital costs. Neither the Japanese nor the Germans have approached their designs from the critical need to build both very light and unlinked vehicles capable of off-line loading and

unloading. The result is that that guideway becomes unnecessarily massive, with incumbent high costs. Further, the more massive the guideway, the more expensive it becomes to elevate it in order to use existing highway rights-of-way eliminating the need for at-grade crossings.

The keys to eventual commercialization of maglev technology will be its use as an airline technology for relief of air traffic congestion, employing a light weight design that can reduce the system cost, and use of existing rights-of-way to further minimize costs and disruptions.

TESTIMONY
PRESENTED ON BEHALF OF
THE CITY OF LAS VEGAS, NEVADA

BEFORE THE

SUBCOMMITTEE ON WATER RESOURCES, TRANSPORTATION AND
INFRASTRUCTURE; ENVIRONMENT AND PUBLIC WORKS COMMITTEE
UNITED STATES SENATE

ON

THE USE OF THE INTERSTATE HIGHWAY RIGHT-OF-WAY FOR
MAGNETIC LEVITATION HIGH SPEED TRANSPORTATION SYSTEMS

February 26, 1988

MR. CHAIRMAN, MEMBERS OF THE COMMITTEE, MY NAME IS RICHARD WELCH AND I AM A SENIOR MANAGEMENT ANALYST FOR THE CITY MANAGER OF LAS VEGAS. I AM HERE TODAY REPRESENTING THE PROPOSED LAS VEGAS TO SOUTHERN CALIFORNIA SUPER SPEED TRAIN PROJECT. WHILE THIS PROJECT HAS IMPORTANT IMPLICATIONS FOR OUR CITY AND FOR SOUTHERN CALIFORNIA, IT IS ALSO A SUBJECT THAT HAS FAR-REACHING CONSEQUENCES FROM THE VIEWPOINT OF INTERNATIONAL AND NATIONAL TRANSPORTATION.

THE NEED FOR A HIGH SPEED OR SUPER SPEED TRAIN SYSTEM WAS FIRST ARTICULATED BY HOWARD HUGHES IN RESPONSE TO A STUDY CONDUCTED BY THE LOS ANGELES AIRPORT AUTHORITY IN THE MID- TO LATE 1960'S, WHICH WAS CONCERNED ABOUT THE CONGESTION, NOISE AND PHYSICAL IMPACT THE SUPERSONIC TRANSPORTS WOULD HAVE ON THE LOS ANGELES BASIN. LATER, THIS SAME PROPOSAL WAS ARTICULATED ONCE AGAIN BY BUSINESS AND COMMUNITY LEADERS IN THE IMMEDIATE WAKE OF THE OIL SHORTAGE AND PRICE INCREASES IN THE EARLY AND LATE 1970'S. HIGHER COSTS AND POTENTIAL LIMITED AMOUNTS OF FUEL FOR ALL FORMS OF TRANSPORTATION, PARTICULARLY FOR AUTOMOBILES AND COMMERCIAL AIRLINES, REDUCED DISCRETIONARY TRAVEL, UPON WHICH OUR ECONOMY IS DEPENDENT. THE CONCEPT OF A SUPER SPEED TRAIN SYSTEM WAS BORN AS AN ALTERNATIVE TO THE PETROLEUM-DEPENDENT MODES OF TRANSPORTATION THAT CURRENTLY EXIST. SOUTHERN CALIFORNIA IS THE LARGEST SINGLE

SOURCE OF VISITORS TO LAS VEGAS. THEREFORE, THE LAS VEGAS--SOUTHERN CALIFORNIA CORRIDOR EMERGED AS THE LOGICAL FOCUS FOR DEVELOPMENT OF A SUPER SPEED TRAIN SYSTEM.

AN INITIAL STUDY REFERRED TO AS PHASE I WAS UNDERTAKEN TO DETERMINE THE FEASIBILITY OF A SUPER SPEED TRAIN SYSTEM. THE INITIAL STUDY WAS CONDUCTED BY THE BUDD COMPANY; THEY WERE ASSISTED BY THE BECHTEL ORGANIZATION.

THE RESULTS OF THE PHASE I STUDY, CONCLUDED IN JANUARY, 1983, SHOWED THE FOLLOWING:

CONSIDERING BOTH HIGH SPEED AND SUPER SPEED SYSTEMS, ONLY THE SUPER SPEED APPROACH IS LIKELY TO GENERATE ADEQUATE RIDERSHIP IN THE SOUTHERN CALIFORNIA--LAS VEGAS CORRIDOR. MAGNETIC LEVITATION OFFERS THE GREATEST TECHNOLOGICAL PROMISE FOR ACHIEVING SUPER SPEED REVENUE SERVICE. SYSTEM REVENUE IS SUFFICIENT TO COVER OPERATING AND CAPITAL COSTS AS LONG AS EXISTING RIGHTS-OF-WAY ARE USED FOR THE MAJORITY OF THE SYSTEM GUIDEWAY.

THE BOTTOM LINE CONCLUSION WAS THAT THE PROJECT WAS FOUND TO BE FEASIBLE AND THE RECOMMENDATION WAS TO PROCEED WITH ADDITIONAL STUDIES, PARTICULARLY IN THE AREA OF RIDERSHIP FORECASTS.

SHORTLY AFTER THE INITIAL PHASE I STUDY WAS COMPLETED IN 1983, THE FEDERAL RAILROAD ADMINISTRATION AGREED TO FUND THE MORE

DETAILED STUDY CALLED FOR IN PHASE II. THIS PHASE II STUDY WAS DIVIDED INTO 5 SPECIFIC AREAS: RIDERSHIP VERIFICATION, TECHNOLOGY ASSESSMENT, SOCIOECONOMIC IMPACTS, ENVIRONMENTAL REVIEW, AND ORGANIZATIONAL/FINANCIAL PLANNING. THIS STUDY WAS CONDUCTED BY 5 INDEPENDENT CONTRACTORS AND WAS COORDINATED BY A SIXTH CONSULTANT.

THE PHASE II STUDY FINDINGS WERE POSITIVE. THE RIDERSHIP STUDY WAS CONDUCTED BY BARTON-ASCHMAN ASSOCIATES AND SHOWED SUFFICIENT RIDERSHIP TO SUPPORT THE SYSTEM. STARTING IN 1995, AT LEAST 4 MILLION RIDERS WILL USE THE SYSTEM. THIS NUMBER WILL GROW TO AS MUCH AS 6 MILLION BY THE YEAR 2025.

THE ENVIRONMENTAL IMPACT STUDY WAS CONDUCTED BY URS COMPANY. THEY DISCOVERED NO INSURMOUNTABLE ENVIRONMENTAL ISSUES THAT WOULD STOP THE PROJECT.

APPLIED ECONOMIC SYSTEMS WAS THE SOCIOECONOMIC CONSULTANT. THE SYSTEM WILL GENERATE \$4.6 BILLION IN DIRECT AND INDIRECT BENEFITS IN SOUTHERN CALIFORNIA DURING THE 5 TO 7 YEAR CONSTRUCTION PERIODS. THIS TRANSLATES TO 11,000 NEW JOBS.

IN LAS VEGAS, BENEFITS FROM THE SYSTEM WILL BE MOST SIGNIFICANT STARTING IN 1995, WHEN THE NEW VISITORS TO LAS VEGAS AS A RESULT OF THE SUPER SPEED TRAIN (I.E. VISITORS THAT WOULD NOT COME TO LAS VEGAS WITHOUT THE SYSTEM) WILL GENERATE AN ADDITIONAL \$360

MILLION A YEAR IN LOCAL SALES. THE OVERALL ECONOMIC BENEFIT OF THESE ADDITIONAL SALES DOLLARS WILL BE OVER \$600 MILLION A YEAR STARTING IN THE YEAR 1995. THIS WILL RESULT IN THE CREATION OF 13,000 NEW FULL-TIME JOBS.

THE ORGANIZATIONAL/FINANCIAL PLAN WAS DONE BY ROBERT J. HARMON AND ASSOCIATES, AND THEY CONCLUDED THAT NOT ONLY CAN THE PROJECT BE FINANCED, BUT THE SYSTEM WILL GENERATE A SUFFICIENT RATE OF RETURN ON INVESTMENT IN THE LONG TERM TO ATTRACT EQUITY INVESTORS. THE BIG ISSUE IN THIS REGARD IS THE SOURCE OF THE \$2.5 BILLION CONSTRUCTION LOAN. THE FINANCING SCENARIO CALLS FOR A FOREIGN SUPPLIER/NATION TO PROVIDE THIS FINANCING.

FINALLY THE TECHNOLOGICAL ASSESSMENT CONDUCTED BY THE CANADIAN INSTITUTE OF GUIDED GROUND TRANSPORT FOUND THAT THE GERMAN TRANSRAPID MAGLEV AND THE SECOND GENERATION VERSION OF THE FRENCH TGV WILL BE AVAILABLE FOR DEPLOYMENT BY 1995.

WE ARE PROUD TO HAVE MOVED FORWARD TOWARD THE IMPLEMENTATION STAGE. NEVADA SENATE BILL 406 AND CALIFORNIA ASSEMBLY BILL 1839 WERE ENACTED BY THE RESPECTIVE STATE LEGISLATURES DURING THE SUMMER AND FALL OF 1987. THE BILLS CREATED THE CALIFORNIA-NEVADA SUPER SPEED GROUND TRANSPORTATION COMMISSION COMPRISED OF 8 MEMBERS FROM EACH STATE. THE BI-STATE COMMISSION WILL CONVENE IN

MARCH OR APRIL, 1988, AND WILL CONCLUDE ITS WORK BY JANUARY 1, 1992, BY WHICH TIME THE ACTUAL CONSTRUCTION IS SCHEDULED TO BEGIN.

ONE OF THEIR SPECIFIC TASKS WILL BE TO ARRANGE FOR THE USE OF THE RIGHTS-OF-WAY FOR THE LAS VEGAS--SOUTHERN CALIFORNIA SYSTEM.

WE BELIEVE THAT THE USE OF THE INTERSTATE HIGHWAY RIGHT-OF-WAY FOR THE PURPOSE OF IMPLEMENTING A SUPER SPEED GROUND TRANSPORTATION SYSTEM MAKES THE SYSTEM COST EFFECTIVE AND INCREASES THE CHANCES OF THE PROJECT'S BEING A SUCCESSFUL PRIVATE VENTURE.

IN REACHING THIS CONCLUSION, SEVERAL ROUTES WERE SURVEYED FOR THE POTENTIAL SUPER SPEED TRAIN CORRIDOR. ONE ROUTE FOLLOWED THE EXISTING RAIL LINE, ANOTHER FOLLOWED THE POWER LINES, AND THE SELECTED ROUTE FOLLOWED THE INTERSTATE 15 HIGHWAY. A BRAND NEW RIGHT-OF-WAY SYSTEM WAS ALSO CONSIDERED.

IN SELECTING THE INTERSTATE HIGHWAY AS THE THE BEST ROUTE FOR THE MODEL STUDY, THE FOLLOWING CRITERIA WERE USED TO ASSESS THE POTENTIAL ROUTES.

ROUTE LENGTH

THE LENGTH OF A ROUTE DETERMINES TO A SUBSTANTIAL DEGREE THE SYSTEM COST AND THE TRAVEL TIME. THE GUIDEWAY INSTALLATION COST

REPRESENTS BY FAR THE LARGEST PORTION OF THE TOTAL SYSTEM COST. THIS DEMANDS A SEARCH FOR ROUTES REPRESENTING MINIMUM DISTANCE AND TRAVEL TIME. THE EXISTING RAIL RIGHT-OF-WAY WAS ELIMINATED DUE TO ITS LENGTH.

LAND ACQUISITION

LAND ACQUISITION FOR TRANSIT SYSTEMS TRAVERSING LARGE AREAS IS TIME-CONSUMING AND COSTLY. THUS, ROUTE SECTIONS WHICH ARE LIKELY TO EXPERIENCE DELAYS IN LAND ACQUISITION SHOULD BE AVOIDED AS MUCH AS POSSIBLE. THE CONSIDERATION OF ACQUIRING NEW RIGHT-OF-WAY FOR A NEW RAIL LINE WAS ELIMINATED ON THE PREMISE THAT IT WOULD NOT BE COST EFFECTIVE.

MAXIMUM GRADE LIMITATIONS

GRADE LIMITATIONS IN SUPER SPEED GROUND TRANSPORTATION SYSTEMS WEIGH HEAVILY ON ROUTE DETERMINATION. THE POWER LINES TRAVERSING MOUNTAINOUS TERRAIN ARE NOT LIMITED BY GRADE RESTRICTIONS SO THE REQUIRED GRADES FOR THESE RIGHTS-OF-WAYS, WHICH WILL EXCEED 10%, CANNOT BE NEGOTIATED BY EVEN A SUPER SPEED SYSTEM. THIS ELIMINATED THE POSSIBILITY OF THE ROUTE FOLLOWING THE POWER LINES.

BY USING THESE CRITERIA, THE INTERSTATE HIGHWAY SYSTEM EMERGED AS THE BEST POSSIBLE ROUTE FOR THE SUPER SPEED TRAIN. THE ROUTE

LENGTH WAS REDUCED TO A MINIMUM; THE GRADES DID NOT EXCEED THE CAPACITY OF THE MAGLEV VEHICLE AND LAND ACQUISITION WAS MINIMAL, MAKING IMPLEMENTATION OF THE SYSTEM COST EFFECTIVE.

THE INTERSTATE HIGHWAY ALSO PROVIDED THE BEST ACCESS TO THE GUIDEWAY FOR CONSTRUCTION AND MAINTENANCE WORK. AS YOU CAN IMAGINE, THE POWER LINE RIGHT-OF-WAY WAS VERY REMOTE AND EVEN THE RAIL RIGHT-OF-WAY WAS DIFFICULT TO GET TO FOR CONSTRUCTION PURPOSES. IN ADDITION, THE INTERSTATE RIGHT-OF-WAY PROVIDED THE BEST ACCESS FOR EMERGENCY EVACUATION, SHOULD SUCH A SITUATION ARISE.

BASED ON ALL OF THESE FACTS, THE OBVIOUS ROUTE FOR THE SUPER SPEED GROUND TRANSPORTATION SYSTEM BETWEEN SOUTHERN CALIFORNIA AND LAS VEGAS IS TO USE THE INTERSTATE 15 ALIGNMENT.

IT IS OUR OPINION THAT SENATE BILL 2072 WILL PROVIDE GREAT BENEFITS TO THE LAS VEGAS--SOUTHERN CALIFORNIA SUPER SPEED TRAIN PROJECT BY CLEARLY DEFINING THE PROCESS BY WHICH RIGHTS-OF-WAY ALONG FEDERAL-AID HIGHWAYS MAY BE USED FOR MAGNETIC LEVITATION SYSTEMS. WE WHOLEHEARTEDLY SUPPORT SENATE BILL 2072.

I MIGHT ALSO ADD THAT THIS COMMITTEE HAS ALSO CONSIDERED ANOTHER BILL RECENTLY, SB 1794, DEALING WITH MAGNETIC LEVITATION TECHNOLOGY. WE SUBMITTED TESTIMONY IN SUPPORT OF THAT BILL AT

THE TIME OF YOUR PREVIOUS HEARING. WE STILL STRONGLY SUPPORT
THIS PROPOSAL.

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Testimony on the High Speed Ground Transportation

**Presented to the Subcommittee on Water Resources, Transportation,
and Infrastructure of the
Committee on Environment and Public Works
by**

Dr. Richard J. Gran

**Director of Advanced Concepts In Corporate Technology
Grumman Corporation
Bethpage, New York 11714**

February 26, 1988

Mr. Chairman.

I represent the Grumman Corporation today to provide some insight on how we in industry perceive a magnetic levitation transportation system.

Most of the scientific issues associated with conventional superconductors, and the design of a high speed train are understood. The Japanese are in the process of demonstrating a train that uses superconductors for lift. For conventional superconductors, the scientific basis of magnetic levitation is understood. The Japanese and French have operational high speed trains that demonstrate that the aerodynamic and operational problems can be solved. There are however political and technical problems that are not solved.

Political and technical issues must be understood before a large scale prototype is developed. Failure to understand these issues could lead to the development of the wrong system, and a significant delay in the start of an operating system. It is possible that we can avoid some errors by the garnering some lessons from the early history of the steam locomotive and the steam railroad.

Today we are in the same position that Richard Trevithick was in when in 1797 he demonstrated three models of a tracked vehicle. The Trevithick train was built by February of 1804. It was 1829, though, before the first realistic solution for such a vehicle was in place. The realistic solution provided the technology for solving the political problem that this vehicle posed.

How could someone build an inexpensive right of way that local governments could afford, and that the national government would support? Many systems were tested. Most failed because the track design was unable to sustain the tremendous driving loads that a steam locomotive produced. The technology that finally made the railroad possible was the rolled iron edge rail patented in 1829 by John Blenkinsop. This rail allowed the first railway system to be built by 1831. Thirty four years after the concept was demonstrated a system was in place.

The first railway that evolved from this early work was practical from all viewpoints. The trains were inexpensive, and producible with the existing technology. The track was easy to manufacture, and relatively inexpensive to install. The technology provided a better means for transporting freight, so a market existed for the system. In 1831 the government was willing to back the development of the right-of-way. Because of this, the industry of the time was willing to put its own capital on the line to manufacture the vehicles.

In 1988 we are at the same technical and political crossroad with respect to fast magnetically levitated transportation system. The existing ground transport system can not provide the required speed. Steel tracks with welded joints, even when smoothed by frequent re-welding and grinding, do not provide a smooth enough surface for high speed trains. Current ground transportation systems are at or near their capacity. There is a clear market for an improved transport system.

American industry will make a commitment to a magnetically levitated vehicles if the government agrees to attack the political problems associated with obtaining right-of-way. The government can only do this if they have a reasonable understanding of the cost. This cost comes from an understanding of the size, shape and expense of the track that a magnetically levitated vehicle requires.

We are in a circle. Government needs technical answers to make the decision to support the political decisions. Industry needs commitment from the government that a transportation system will be put into place before they will invest money solving the technical issues.

A demonstration system with the goal of solving the technical problems associated with train and track will break this circle. The government should begin funding an orderly program that first gives the research and technology development that is required. The emphasis should be on those technologies that are critical to a successful system. These include the track design, the aerodynamics of the train and the track and the interaction of the moving vehicle with its local environment. The propulsion and levitation system design should also be developed through detailed R&D. The answers to the technical questions can be used to allow a second phase where the design of a prototype system would commence. This orderly design and development cycle follows the historical lessons from the introduction of the steam railway.

The approach I have outlined will encourage industry to take reasonable financial risks to develop the transportation system of the future.

As new technology for transporting people and merchandise is introduced, it alters the way people work, communicate and play. If history is any guide, the combined effort of government and industry in building a high speed transportation system based on magnetic levitation technology will yield a harvest of great benefits. There is an incentive. The proposed legislation will break the circle I described and make it happen. Lets do it!



STATEMENT BY
CARL H. ROSNER
PRESIDENT
INTERMAGNETICS GENERAL CORPORATION
ON S. 1794

SUBCOMMITTEE ON WATER RESOURCES, TRANSPORTATION
AND INFRASTRUCTURE

SENATE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

FEBRUARY 26, 1988

STATEMENT BY
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MR. CHAIRMAN, LADIES AND GENTLEMEN:

ON BEHALF OF INTERMAGNETICS GENERAL CORPORATION (IGC), AND AS ITS PRINCIPAL FOUNDER AND PRESIDENT, I AM PLEASED TO HAVE THE OPPORTUNITY TO ADDRESS YOU ON THE SUBJECT OF INCORPORATING SUPERCONDUCTIVE TECHNOLOGY INTO A MOST EXCITING AND EVEN ESSENTIAL TECHNOLOGICAL DEVELOPMENT. NAMELY, THE FIRST SERIOUS EFFORT TO PLAN AND EXECUTE A DRAMATIC IMPROVEMENT IN OUR TRANSPORTATION SYSTEM SUITABLE FOR OUR COUNTRY'S NEEDS INTO THE 21ST CENTURY.

INTERMAGNETICS (IGC) IS A RAPIDLY GROWING SMALL BUSINESS, THAT, SINCE A SPIN-OFF FROM GENERAL ELECTRIC CO. IN 1971, HAS DEVOTED ITSELF TO THE COMMERCIALIZATION OF SUPERCONDUCTIVE TECHNOLOGY. HENCE, WE ARE WELL AWARE OF THE VERY SIGNIFICANT MAGNETIC LEVITATION PROJECTS THAT ARE BEING CARRIED OUT IN JAPAN AND EUROPE - BOTH OF WHICH COUNTRIES, I MIGHT ADD, I'VE HAD THE OPPORTUNITY TO VISIT. THESE COUNTRIES HAVE BEEN COMMITTED TO THE DEMONSTRATION OF THE FEASIBILITY OF UTILIZING SUPERCONDUCTORS FOR HIGH-SPEED TRANSPORTATION. THEIR PURSUIT OF THESE PROJECTS IS ANOTHER INDICATION OF THEIR FORESIGHT AND ABILITY TO IMPLEMENT PROJECTS WITH LONGER-RANGE PAY-OFFS WHEN COMPARED WITH THE SEEMING LACK OF VISION BY U.S. ORGANIZATIONS. IN THE FACE OF PIONEERING MAG-LEV ACTIVITIES WHICH ORIGINATED IN THIS COUNTRY, I MIGHT NOTE HERE, THAT BOTH THE U.S. AND CANADA DECIDED UPON TERMINATING THEIR RESPECTIVE MAG-LEV ACTIVITIES AS FAR BACK AS THE MID-1970'S.

IF THE RATIONALE FOR OUR DECISIONS THEN WAS THE LACK OF BETTER SUPERCONDUCTORS, THE MOST RECENT BREAKTHROUGH IN HIGHER-TEMPERATURE SUPERCONDUCTORS SHOULD CERTAINLY BECOME THE NEEDED STIMULUS EMBODIED IN THE PROGRAM OUTLINED IN S. 1794.

I HAPPEN TO BELIEVE THAT EVEN WITHOUT THIS UNEXPECTED SCIENTIFIC BREAKTHROUGH IN NEWER SUPERCONDUCTORS, THE TECHNOLOGY OF MAGNETIC LEVITATION SHOULD BE PURSUED VIGOROUSLY, BECAUSE IT EMBODIES DEMANDING ENGINEERING CHALLENGES THAT NEED TO BE SOLVED SUCCESSFULLY. ALREADY MANY ASPECTS OF THESE HAVE ABLY BEEN SURMOUNTED BY JAPAN AND GERMANY. THE JUSTIFICATION FOR THIS VIEWPOINT IS THAT THE EXPERIENCE GAINED BY THEM AND PERSPECTIVES DEVELOPED OF OVERALL SYSTEM RELATED PROBLEMS, WILL BENEFIT APPLICATIONS OF SUPERCONDUCTIVE TECHNOLOGY MUCH MORE BROADLY, RANGING OVER VITALLY IMPORTANT ENERGY AND ELECTRIC EQUIPMENT BASED PRODUCT OPPORTUNITIES.

WE AT IGC DESIGN AND MANUFACTURE THE BASIC AND KEY ELEMENTS NECESSARY FOR SUPERCONDUCTOR EQUIPMENT; NAMELY THE SUPERCONDUCTIVE WIRE, THE MAGNETS AND THE LOW-TEMPERATURE COOLING EQUIPMENT, I.E. CRYOGENIC EQUIPMENT NECESSARY BOTH FOR CONVENTIONAL AND THE NEW SUPERCONDUCTOR APPLICATIONS. WE HAVE WATCHED WITH A COMBINATION OF ADMIRATION AND AWE HOW, ESPECIALLY JAPAN, HAS USED THEIR LONG-RANGE MAG-LEV, FUSION AND ACCELERATOR PROGRAMS AS VISIBLE AND ATTRACTIVE TARGETS, TO BUILD A VERY COMPETENT AND INCREASINGLY COMPETITIVE INDUSTRIAL BASE IN SUPERCONDUCTIVITY, SUCH THAT THEY CAN NOW LAY CLAIM TO A LEVEL OF ENGINEERING LEADERSHIP IN HAVING THE WHEREWITHAL TO APPLY SUPERCONDUCTORS TO MANY POSSIBLE PRODUCT AREAS.

IT IS THIS ABILITY TO HAVE THE FORESIGHT AND A BROADER PERSPECTIVE, INCLUDING THE PATIENCE TO INVEST IN THE FUTURE, IN AN AREA THAT MUST, BY NECESSITY, BE SUBJECT TO GOVERNMENT-INDUSTRY PARTNERSHIP WHERE WE STILL HAVE A LOT TO LEARN, ---- HOPEFULLY BEFORE WE RIDE IN FOREIGN-BUILT MAG-LEV TRAINS THAT INEVITABLY WILL CRISS-CROSS THE COUNTRY IN THE FAR-FUTURE.

ONLY A FEW DAYS AGO DID I LISTEN TO A PRESENTATION BY A GENTLEMAN AT THE WORLD CONGRESS ON SUPERCONDUCTIVITY IN HOUSTON, WHICH OUTLINED FUTURISTIC VISIONS AND ARTISTS CONCEPTS OF MAG-LEV SYSTEMS INCORPORATED INTO CITY SKYLINES IN JAPAN.

WE IN THE U.S. INDUSTRY TEND TO BE GOVERNED IN OUR DECISIONS BY SHORT-TERM ECONOMIC REALITIES, SOMETIMES IMPOSED BY UNREALISTIC WALL STREET EXPECTATIONS, BUT MORE OFTEN BY THE FACT THAT EFFICIENCY TRANSLATES ITSELF INTO ECONOMIC GAINS. THEREFORE, IT MAY BE DIFFICULT TO JUSTIFY, WHAT ADMITTEDLY WILL HAVE TO BE A VERY LARGE EXPENDITURE REQUIRED TO DEVELOP A MAG-LEV SYSTEM AND INFRA-STRUCTURE, BOTH WITHIN A STATE AND ULTIMATELY NATIONALLY, THAT CANNOT BE ATTACKED AS BEING ECONOMICALLY IRRESPONSIBLE.

YET, THE INCREASINGLY RAPID PACE OF COMMERCIALIZATION EFFORTS BY MORE AND MORE INDUSTRIAL NATIONS, INDICATE THAT LARGER-SCALE INVESTMENTS MADE EARLY ON, PROVIDE A VIRTUALLY INSURMOUNTABLE MARKET LEAD, THAT LATE-COMERS OFTEN FIND IMPOSSIBLE TO OVERCOME. HENCE, THE QUESTION MAY BE ASKED - ARE WE TOO LATE TO APPLY SUPERCONDUCTIVE TECHNOLOGY TO OUR TRANSPORTATION NEEDS, AS EMBODIED IN S. 1794? MY ANSWER WOULD, IN THIS CASE, BE A RESOUNDING NO, BUT TIME IS SHORT FOR A POSITIVE DECISION. ALREADY ENTREPRENEURIALY ORIENTED ORGANIZATIONS ARE PROPOSING TO BRING MAG-LEV TECHNOLOGY DEVELOPED OVERSEAS TO FLORIDA, NEW YORK, NEVADA AND CALIFORNIA. WHAT THESE GROUPS HAVE APPARENTLY RECOGNIZED, THAT THE AMERICAN PUBLIC WILL PAY - EVEN A PREMIUM - FOR THE CONVENIENCE EMBODIED IN NOT FIGHTING TRAFFIC TO GET TO THE AIRPORT, TO NOT HAVE TO SIT AND WAIT ON CROWDED AIRPLANES, THEN TRAVEL ON OVER-CROWDED HIGHWAYS TO THEIR FINAL DESTINATIONS.

SURELY ON A SMALLER SCALE, IN THE AREA OF PREPACKAGED FOOD, ETC. THE PUBLIC PREFERS CONVENIENCE OVER COST ON AN INCREASINGLY SCALE.

MY PREDICTION IS THAT IN A NUMBER OF CONGESTED AREAS IN THE COUNTRY, SUPERCONDUCTIVE BASED MAG-LEV TRANSPORTATION SYSTEMS WILL SIMILARLY BE THE PREFERRED MODE OF TRAVEL, SUCH THAT THESE SYSTEMS WILL MORE THAN PAY FOR THEMSELVES.

IF WE BEGIN NOW, WE CAN STILL EXPLOIT THE NARROW OVERALL ADVANTAGE WE HAVE IN SUPERCONDUCTIVE TECHNOLOGY, AS DEMONSTRATED BY THE SUCCESSFUL INTRODUCTION OF SUPERCONDUCTIVE BASED MEDICAL IMAGING TECHNOLOGY, AND RECAPTURE THE INITIATIVE IN APPLYING SUPERCONDUCTIVE TECHNOLOGY TO MAG-LEV SYSTEMS.

IGC'S FAITH IN THE ENORMOUS COMMERCIAL POTENTIAL OF SUPERCONDUCTIVITY IS BUOYED BY THE FACT, THAT THE EXCITEMENT SURROUNDING HI Tc SUPERCONDUCTOR ACTIVITIES HAVE STIMULATED A LARGE NUMBER OF INDUSTRIES AND ACADEMIC INSTITUTIONS INVOLVED IN ELECTRICAL, ELECTRONIC, CHEMICAL, CERAMIC, MEDICAL AND PHYSICAL DISCIPLINES, TO COLLABORATE IN A MULTI-DISCIPLINARY FASHION THAT BODES WELL FOR THE POTENTIAL FUTURE EFFORTS ON THE PART OF U.S. INDUSTRY TOWARDS GREATER GLOBAL COLLABORATION AND COMPETITIVENESS.

IN THIS REGARD, AND BEFORE CLOSING I WOULD ALSO LIKE TO MENTION THAT I SERVE AS A MEMBER OF THE BOARD OF DIRECTORS OF THE COUNCIL ON SUPERCONDUCTIVITY FOR AMERICAN COMPETITIVENESS. THIS IS A PRIVATELY FUNDED, NON-PROFIT ORGANIZATION COMPOSED OF PRIVATE SECTOR ENTITIES, AS WELL AS UNIVERSITIES AND GOVERNMENT SCIENTISTS, CONCERNED WITH THE APPLICATION AND DEVELOPMENT OF BOTH TRADITIONAL AND HIGH TEMPERATURE SUPERCONDUCTORS. THE CHAIRMAN OF THIS GROUP, DR. GEORGE A. KEYWORTH, WAS UNAVOIDABLY UNABLE TO APPEAR BEFORE THE COMMITTEE TODAY, BUT THE COUNCIL HAS MADE A STATEMENT AVAILABLE WHICH I WISH TO PLACE IN THE RECORD.

IN CONCLUSION, I WISH TO REITERATE STRONGLY THAT WE AT IGC BELIEVE, BOTH THROUGH OUR OWN ACCOMPLISHMENTS AND THOSE OF OUR OVERSEAS COMPETITORS, THAT THE TECHNOLOGY IS HERE TO TACKLE THE CHALLENGING TECHNICAL PROBLEMS THAT LIE AHEAD. THE FINANCIAL MEANS, HOWEVER, AND THE POLITICAL CLIMATE MUST BE PROVIDED THROUGH THE CONCERTED ACTION BY CONGRESS AND THE ASSOCIATED INDUSTRIAL COMMITMENT OVER THE MANY YEARS IN ORDER THAT A PROJECT OF THIS NATURE BE BROUGHT TO A SUCCESSFUL CONCLUSION.

AT THE SAME TIME, THE VISION AND APPROACH EMBODIED IN S. 1794 SHOULD NOT DETER US FROM FUNDING AND PURSUING THE NECESSARY R&D RELATED TO THE OVERALL DEVELOPMENT OF SUPERCONDUCTIVITY, INCLUDING THE SSC PROJECT, WHICH TOGETHER WITH S. 1794 AND OTHER SUPERCONDUCTOR INITIATIVES, SURELY WILL YIELD ENORMOUS BENEFITS FOR OUR NATION AND THE WORLD.

THANK YOU VERY MUCH FOR THE OPPORTUNITY TO EXPRESS MY THOUGHTS ON THIS EXCEEDINGLY IMPORTANT SUBJECT.



IGC CORPORATE FACT SHEET

Intermagnetics General Corporation (IGC) was founded in 1971 as a spin-off from the General Electric Company. In order to continue the business of GE's Superconductive Products Operation, IGC, by issuing promissory notes and equity participation to GE, acquired the then existing technology, personnel and other equipment assets. Intermagnetics remains headquartered in Guilderland, N.Y. and now also has operating plants in Latham, N.Y. and Waterbury, CT.

IGC has since grown to employ over 300 people, and has achieved a recognized position of industry and quality product leadership in the manufacture of both superconductive materials and high field magnets.

Superconductivity is based on the ability of certain metals to carry extremely high levels of electrical current without power loss, when cooled to temperatures approaching absolute zero (minus 459° Fahrenheit, minus 273° Centigrade). Because of their potential for substantial energy conservation and associated ability to create high magnetic fields in the form of electromagnetic windings, superconductors are utilized in a number of areas such as physics, chemistry, energy research, and electromagnetic equipment.

In the first decade of independent corporate existence, the company expanded its expertise to include the technology and manufacture of NbTi wires, as well as enclosures for low temperature environments and related electronic equipment. Today IGC supplies Nb₃Sn and NbTi conductors as well as completely integrated magnet systems, ready to operate.

In 1981, the company became publicly owned and a major fraction of the company's resources were allocated to the further development of materials and of superconductive magnet systems to be used in magnetic resonance imaging (MRI) systems for medical diagnostic purposes. In March 1983, IGC's first whole body imaging magnet, with a field strength of 1.5 Tesla, was delivered to the Columbia-Presbyterian Medical Center in New York City for use in an MRI medical diagnostic system. Another milestone was achieved when the world's first superconductive magnet for use in a truly mobile MRI diagnostic system was delivered by IGC in May, 1984, thereby introducing a concept that is perceived to ultimately help reduce the cost of MRI diagnostics and medical care. While R&D is continuing at IGC to develop other important uses for applied superconductivity, the Company has expanded into new technologies.

In 1987, IGC acquired two subsidiaries, APD Cryogenics Inc, to allow the Company to supply both magnets and cryogenic refrigeration systems at a more cost-effective level; and Field Effects, Inc. to broaden IGC's magnet development capabilities into permanent as well as superconductive magnets. In addition, IGC announced the final development of a new product for mineral separation, MAGSTREAM™, which utilizes either permanent or electromagnets.

Today, IGC is a recognized leader in the design and manufacture of superconductive wire and magnet systems for a wide range of applications. With its new subsidiaries and product lines, IGC continues to develop state-of-the-art high technology products for long-term major scientific, technical and industrial business potential.



COUNCIL on SUPERCONDUCTIVITY for AMERICAN COMPETITIVENESS
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STATEMENT OF THE
COUNCIL ON SUPERCONDUCTIVITY FOR AMERICAN
COMPETITIVENESS
ON S. 1794

SUBCOMMITTEE ON WATER RESOURCES, TRANSPORTATION
AND INFRASTRUCTURE

SENATE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

February 26, 1988

STATEMENT OF THE
COUNCIL ON SUPERCONDUCTIVITY FOR AMERICAN COMPETITIVENESS
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FEBRUARY 26, 1988

The Council on Superconductivity for American Competitiveness (CSAC) is pleased to offer this statement on S.1794, "The Federal Advanced Superconducting Transportation Act," and to discuss the implications of superconductivity in other technology arenas, and the federal government's role in their pursuit.

The Council on Superconductivity for American Competitiveness, which I will refer to as CSAC, is a unique trade group organized around a technology, not a particular business sector. In fact, as the Committee is well aware, superconductivity is a technology that cuts across dozens of very different business sectors. CSAC was formed in part to bring a broad, national perspective to the issues of superconductivity technology that the Congress, the federal agencies, and industry will be confronting as they debate the relative merits of proposals aimed at speeding commercial superconductivity. We at CSAC are also taking on the role of a national clearinghouse of information both for its members and the public with regard to the new scientific advances and government efforts to develop technology at both the high-temperature and low-temperature ends

of the superconductivity spectrum.

The initial Board of Directors of CSAC, which is provided as an addendum for the record, brings together leaders of technology-rich companies, as well as directors of major U.S. national laboratories, leading academics, as well as leading venture capitalists. The very existence of CSAC is evidence that even the most strongly competing companies have mutual interests, and interests that are identical to those of the nation -- to promote a diversity of strong U.S. resources that will allow us to compete in a global marketplace for superconductors.

The vision of magnetically levitated trains using superconducting magnets is not new. The immense magnetic forces that well-known superconducting technologies can produce have long stimulated the imagination of those who would harness that force to create a next-generation, high-speed ground transportation system. Now, the combination of renewed excitement about superconductivity in general, stimulated by the recent discoveries of materials that are superconducting at higher temperatures, and the long-standing and worsening frustration with medium-range travel in busy traffic corridors, has added luster to the potential advantages of the mag-lev train.

Mr. Chairman, an important question that must be looked at is whether the developments in superconductivity, as well as

in other technologies, are likely to change significantly the economics that have so far prevented any serious consideration of mag-lev trains in this country. Indeed, virtually all of transportation in the United States has become dominated by economic, rather than technological issues in recent years, whether we're talking about foreign automobiles, deregulated airlines, or subsidized rail services. What will be admittedly interesting will be the extent to which technology can overcome economics, either by pointing towards more cost-efficient ways of covering the miles, or by making a mode of transportation so attractive that it becomes worth a premium to the traveler.

At this point, the breakthroughs in superconducting materials provide neither of those advantages for rail transportation. We are still trying to understand the basic mechanisms that underly this puzzling new phenomenon, and, frankly, until we do, it is unlikely that we are going to be able to develop high-temperature superconducting magnets that can provide the kinds of magnetic fields needed for mag-lev vehicles. So, with our current state of knowledge, we are still limited to developing superconducting mag-lev technologies using the older, well-proven very low temperature superconductors.

It is for that reason that CSAC views S.1794 with mixed emotions. On the one hand, given the state of technology, we believe mag-lev trains are still largely an issue of socio-economic considerations, a transportation, rather than

a technology issue. The cost differential between ordinary rail and mag-lev, or between mag-lev and car or plane travel, makes current prospects dim. Were we to proceed with development of a system using existing technology, it would surely require substantial subsidy by government to make mag-lev travel costs competitive with existing systems. On the other hand, CSAC is among the strongest supporters for federal research and development on both the low-temperature superconductors that are the basis for what we could do today in mag-lev technology, as well as the importance of continuing aggressive work on the new higher-temperature superconductors. In general, we view with favor any new programs, or legislation, that will encourage, and provide support for, the kinds of research and development that will advance American technology along this dual front.

As you pointed out in earlier statements, Mr. Chairman, we have gone a long time between major leaps in passenger transportation technology. The beauty of a mag-lev system is that it is a blend of two familiar travel techniques: rail system and airplane. Therefore it may tend to be accepted by the public as more than a novelty, but as a truly reliable means of high speed transport. But the main question is, of course, the feasibility of such a system, and whether or not legislation such as S.1794 would expedite its development. The second question is that of timing and priorities. Is America ready to, and should it, devote considerable resources to a transportation system along which the existing rail system cannot operate without

subsidy? And in a larger context, as so well stated in the testimony of Professor Moon before this Committee on January 21, what do we do to bring along those American engineers and scientists who understand this type of transport system in the context of rapidly advancing high-temperature superconducting materials?

We do not pose these questions for the purpose of discounting large-scale projects using superconductivity as a basis for technologically advancing our society. We pose them for the purpose of trying to begin to define what will be the best role for government to play in terms of setting up a national program for the innovative development of superconductivity processes and applications that will lead to a host of applications, transportation among them. Based on statements made by the President last July, the U.S. Government has made superconductivity research and development a national priority. A broad agenda was announced that included steps to encourage greater willingness of industry to cooperate with government in superconductivity R&D. Improving this flow of information, especially from the government labs to the private sector is critical. A secondary effect of highlighting superconductivity as a national priority is that the intense interest in this technology can be used as a spur for improving cooperation among sectors in the development of other areas of technology. One of CSAC's public policy goals is to encourage funding for superconductivity research of the kind that will

build a base for technological developments in coming years. We were pleased to see that some \$128 million dollars were earmarked in FY 88 for superconductivity R&D among various government agencies, and we would anticipate that the President's budget for FY 89, recently transmitted to Congress, would contain increased commitments. As this Committee has recognized, U.S. investments in superconductivity R&D can lead to great payoffs. We realize that the increases in funding over the past year have been spurred primarily by the public's excitement, which mirrored the scientists', about the breakthrough in new materials. CSAC believes one of its major tasks now is to help sustain that new level of research, even though the public excitement about applications may recede while reality catches up with imagination.

CSAC will also advocate, in this Congress, the adoption of a draft measure out of the House Committee on Science, Space and Technology titled "The National Superconductivity, Competitiveness and National Security Act of 1987." This measure focuses on keeping America's competitive advantage in superconductivity by committing sufficient long-term resources toward solving processing and manufacturing problems in parallel with basic research and development. The bill calls for the formation of a national commission on superconductivity and authorizes \$120 million each year for five years for the purposes of R&D among various federal agencies. In CSAC's estimation this type of legislation merits the support of

Congress. It provides for a long-term national program on superconductivity which includes focusing on a variety of emerging technologies utilizing superconductors. The bill also provides for the critical element of manufacturing and processing techniques being investigated along with basic R&D. Mr. Chairman, we ask that you might explore drafting or sponsoring such a measure, and to hold hearings on its merits, to insure that the important issues involving superconductivity industrial competitiveness are aired on a broad range of topics, by the experts, on applied technologies that would include the feasibility of superconducting mag-lev systems. In the shorter term, CSAC would also encourage the Senate to continue support for those programs which could have a direct bearing on America's competitive posture in the long term, such as those programs funded by the Defense Advanced Research Projects Agency (DARPA) and the Office of Naval Research (ONR). Recently, DARPA and ONR selected 20 companies to participate in their high-temperature superconductivity program. This program emphasizes synthesizing, processing, and fabricating superconductive materials in engineering shapes and sizes; manufacturing aspects, such as reproducibility, quality and quantity; and designing and developing new superconducting devices. The total contract value is \$15 million, and out of 202 proposals only 20 could be chosen, not for lack of merit, but for lack of funds. In our estimation, there were probably dozens of these proposals that deserved to be number 21, but were eliminated for lack of resources. But it is in these very

types of programs that the innovations will be made to provide for manufacture of materials that are capable of handling larger currents, that can carry larger magnetic fields, and that are strong, flexible, and resistant to strain -- all of which are qualities that materials must exhibit in order to be adapted to transportation systems, among many other applications. Obviously, this is another example of the need to evaluate the components of a national effort on superconductivity, which was previously mentioned.

Mr. Chairman, CSAC would like to thank the Committee for this opportunity to comment on S.1794. We appreciate your interest in identifying an application for superconductivity that will be a very visible symbol for America's commitment to rejuvenate its competitive spirit in an important area of applied technology utilizing superconductivity. We support the intentions of S.1794, but at the same time ask that the Senate focus attention on the need for an overall federal program that will keep the spotlight on superconductivity as a national priority. The latest advances in higher temperature superconductors have been hailed by the very conservative scientific community of this country as a "once in a generation" scientific achievement. The "Naval Research Review" estimated that the commercial marketplace for products using superconductors would be in the area of \$11-\$36 billion by the year 2000, even before the recent breakthroughs. Given these plaudits by the scientific community and the potential commercial

marketplace, the Senate is wise to be focusing on this large-scale applications in order to let America catch-up and surpass its competitors in mag-lev technology. At the same time, implementation of a program that addresses the equally important applications in defense, electronics, power transmission and storage, medicine and manufacturing will serve to eliminate the prospect that we will once again be the bronze medalists in a competition where we had the talent and abilities, but perhaps not the will, to win the gold.

Thank you.

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